

What next? Potential species replacements for black ash in northern Minnesota in a changing climate

Black Ash Symposium Bemidji, MN

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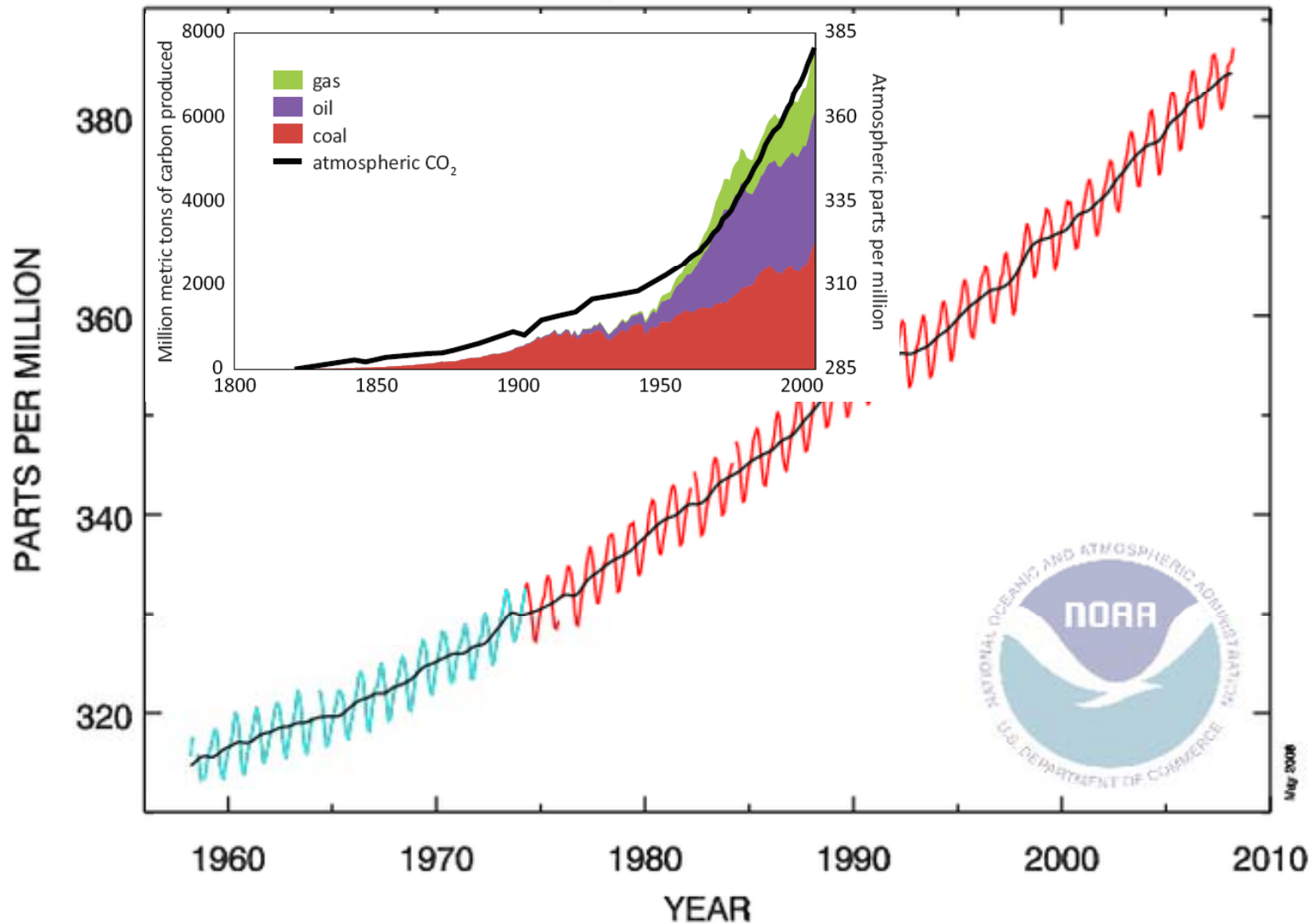
³Ohio DNR, Division of Forestry, Columbus, OH

Outline

- Some general climate trends
- Overview of our climate change modeling approach
- Potential species habitat changes by 2100
- Evaluation of MN FIA data
- Evaluation of Ohio and Michigan plots
- Summary of possible replacements for black ash

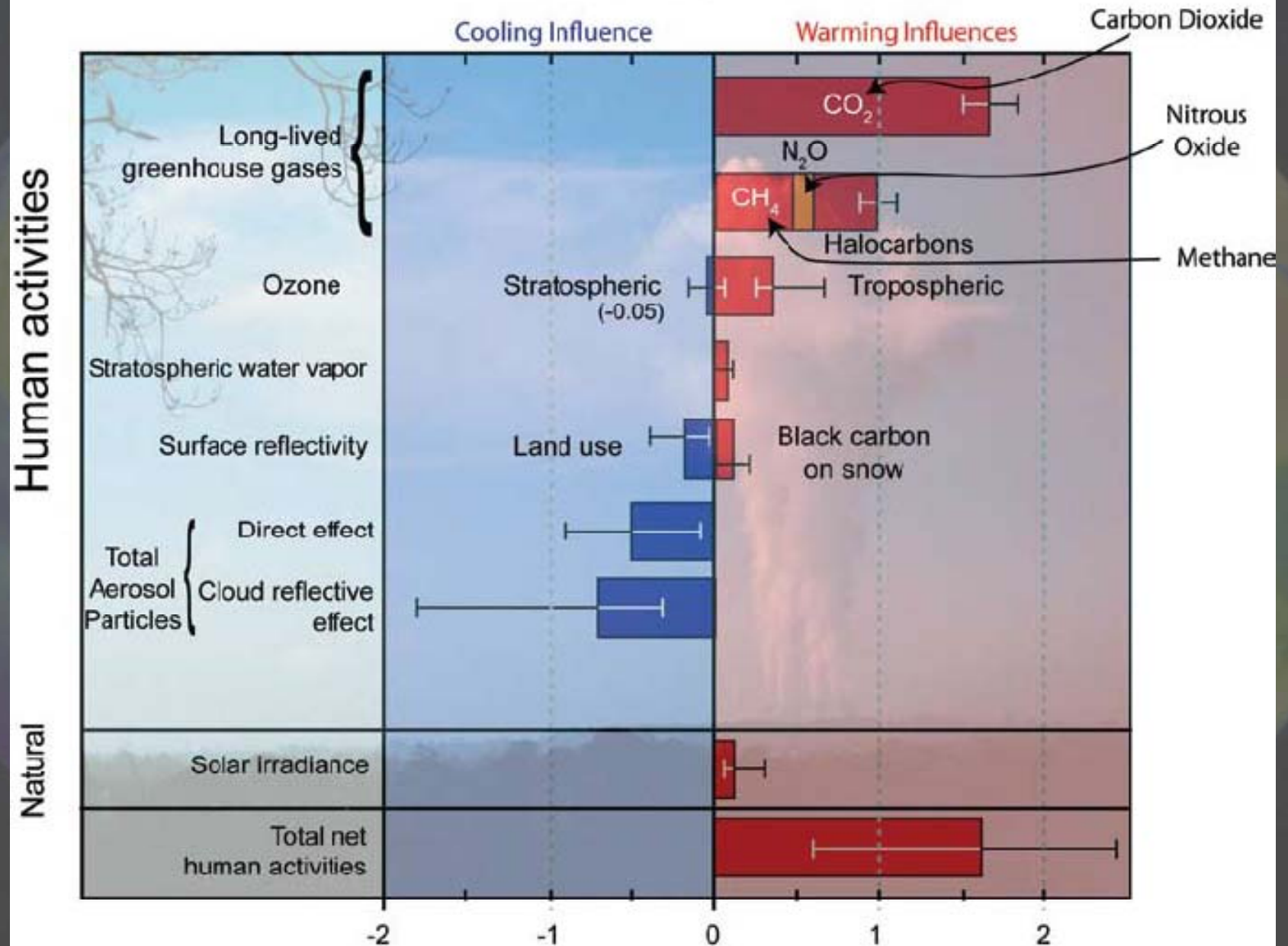
~2 ppm rise per year, now at 387 ppm =
100 ppm more than in 1860

Atmospheric CO₂ at Mauna Loa Observatory

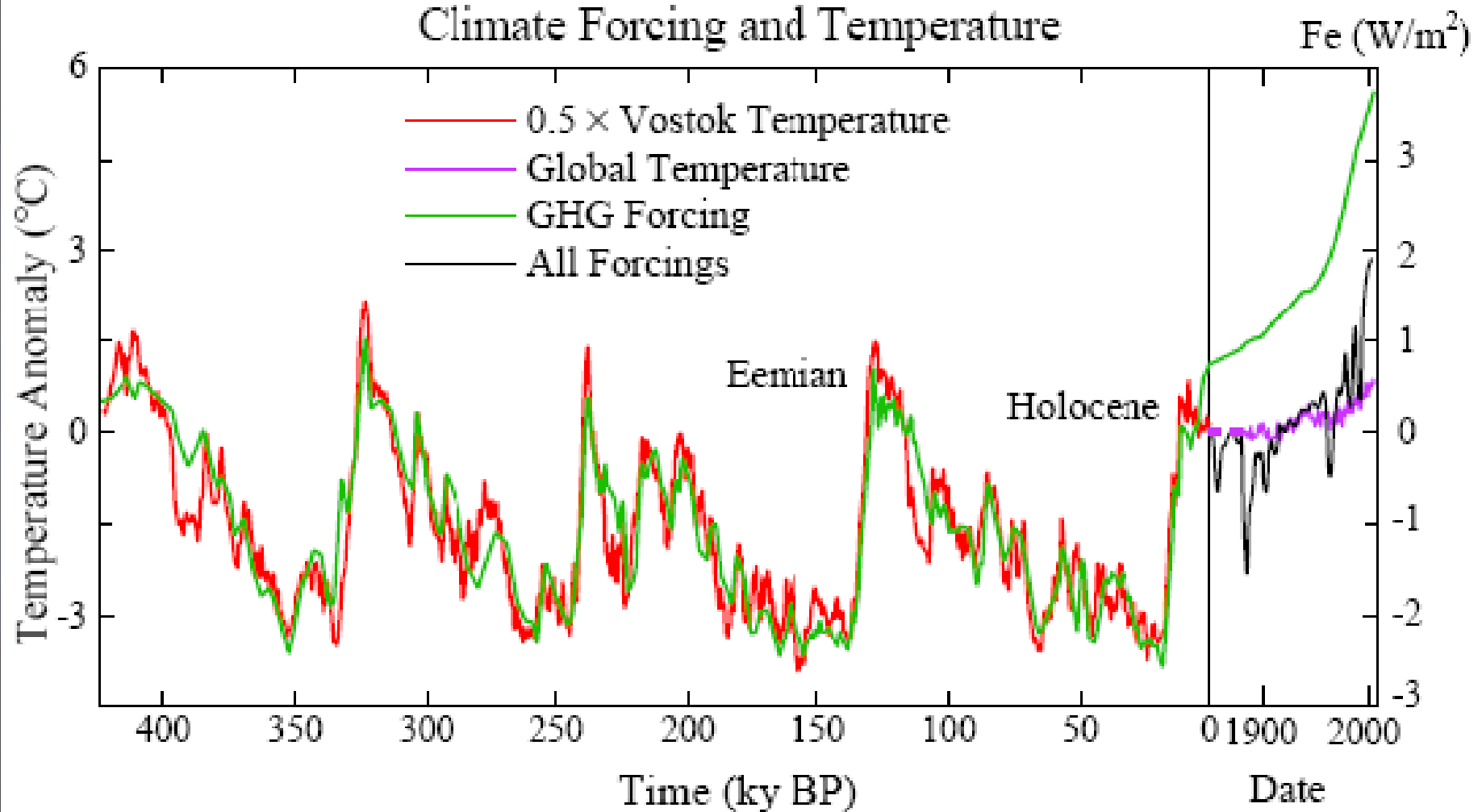


Major Factors Affecting Climate

1950 - Present



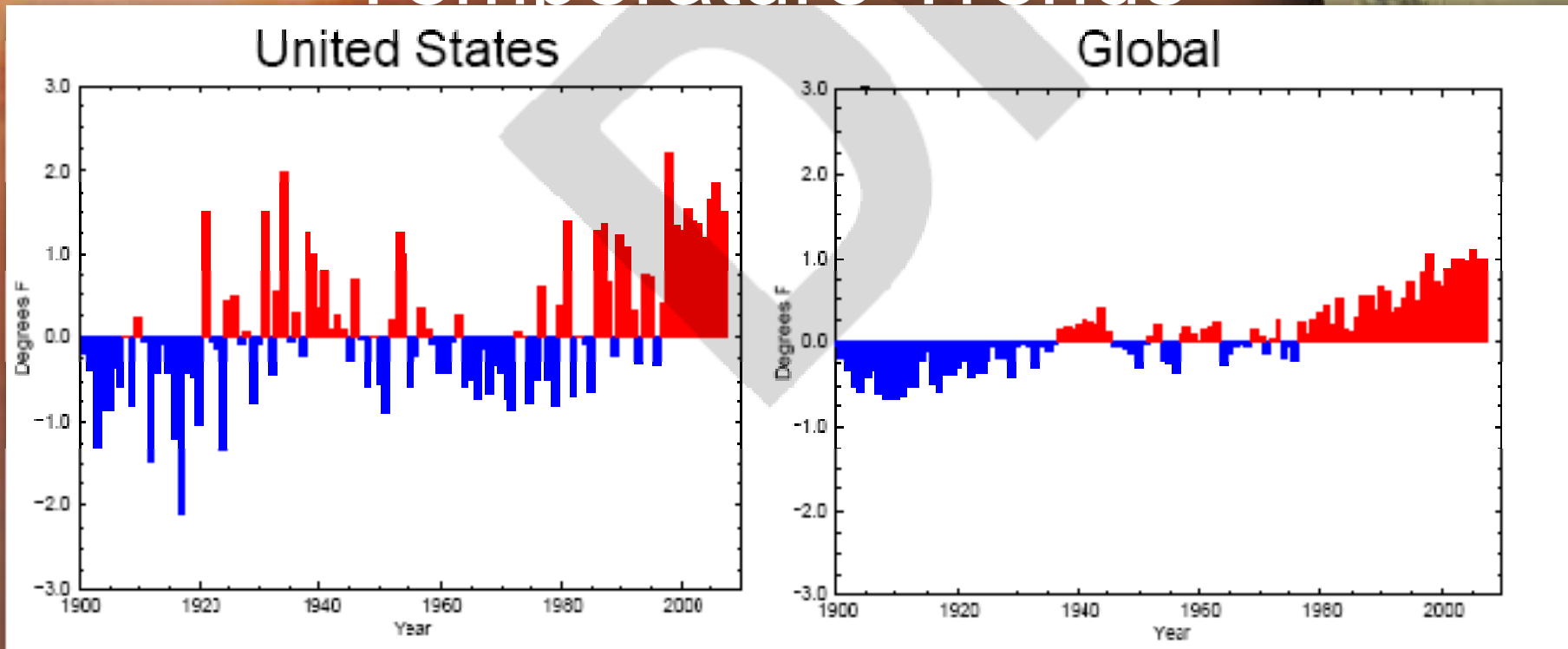
Climate Forcing and Temperature





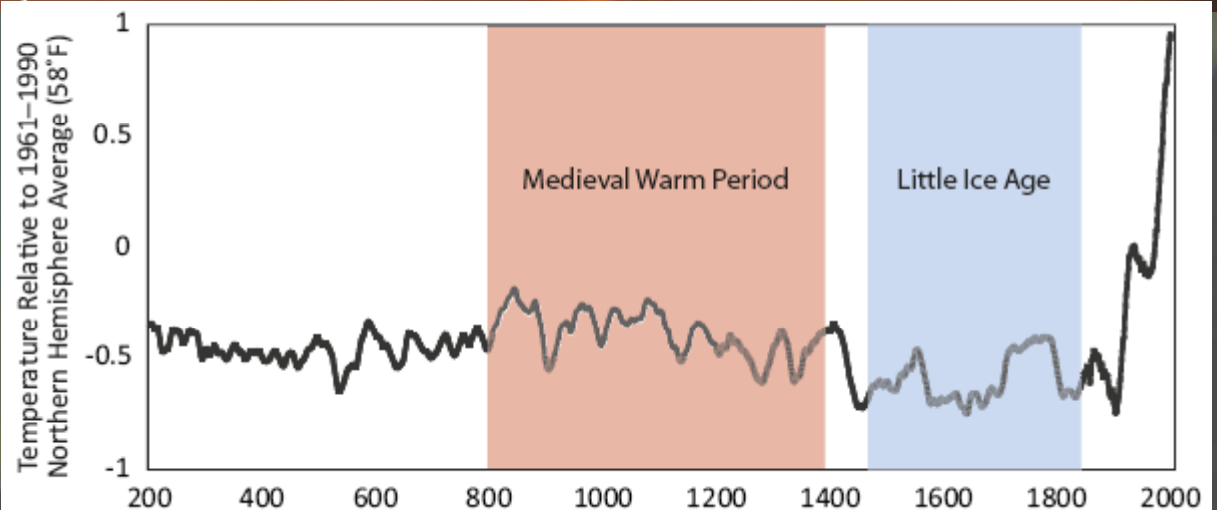
Historic Climatic Trends

Temperature Trends



Annual average temperatures compared to mean baseline.

NOAA, 2009



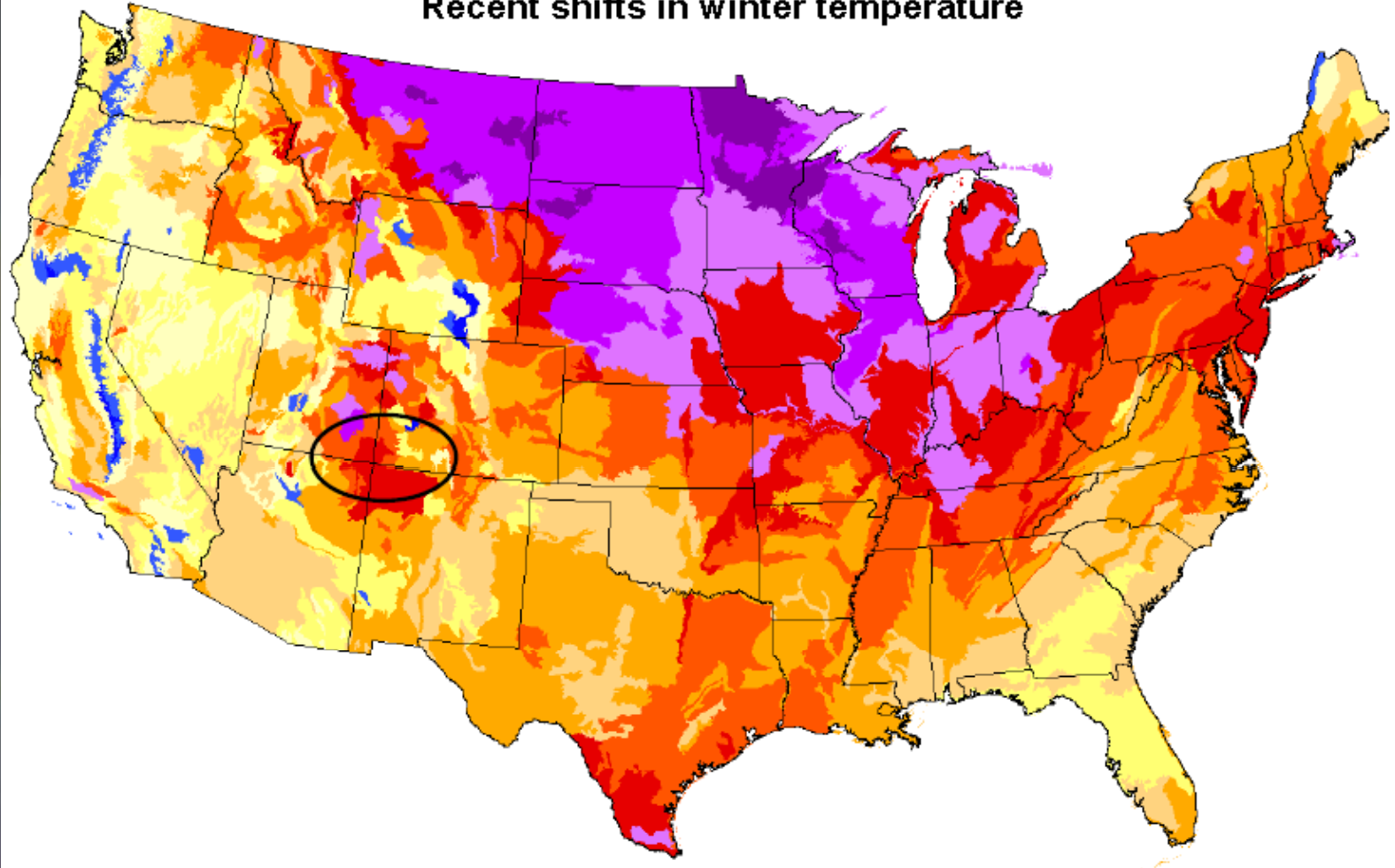


Recent shifts in climatic regimes

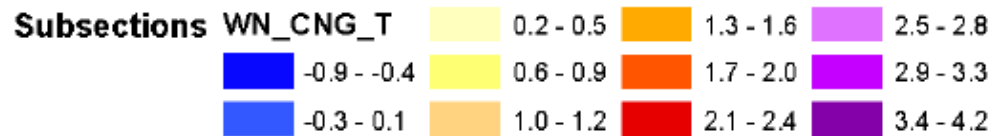
Comparison of components of climatic regimes of
the 1961-1990 versus 1991-2007 periods

From Dave Cleland, USFS, 2010

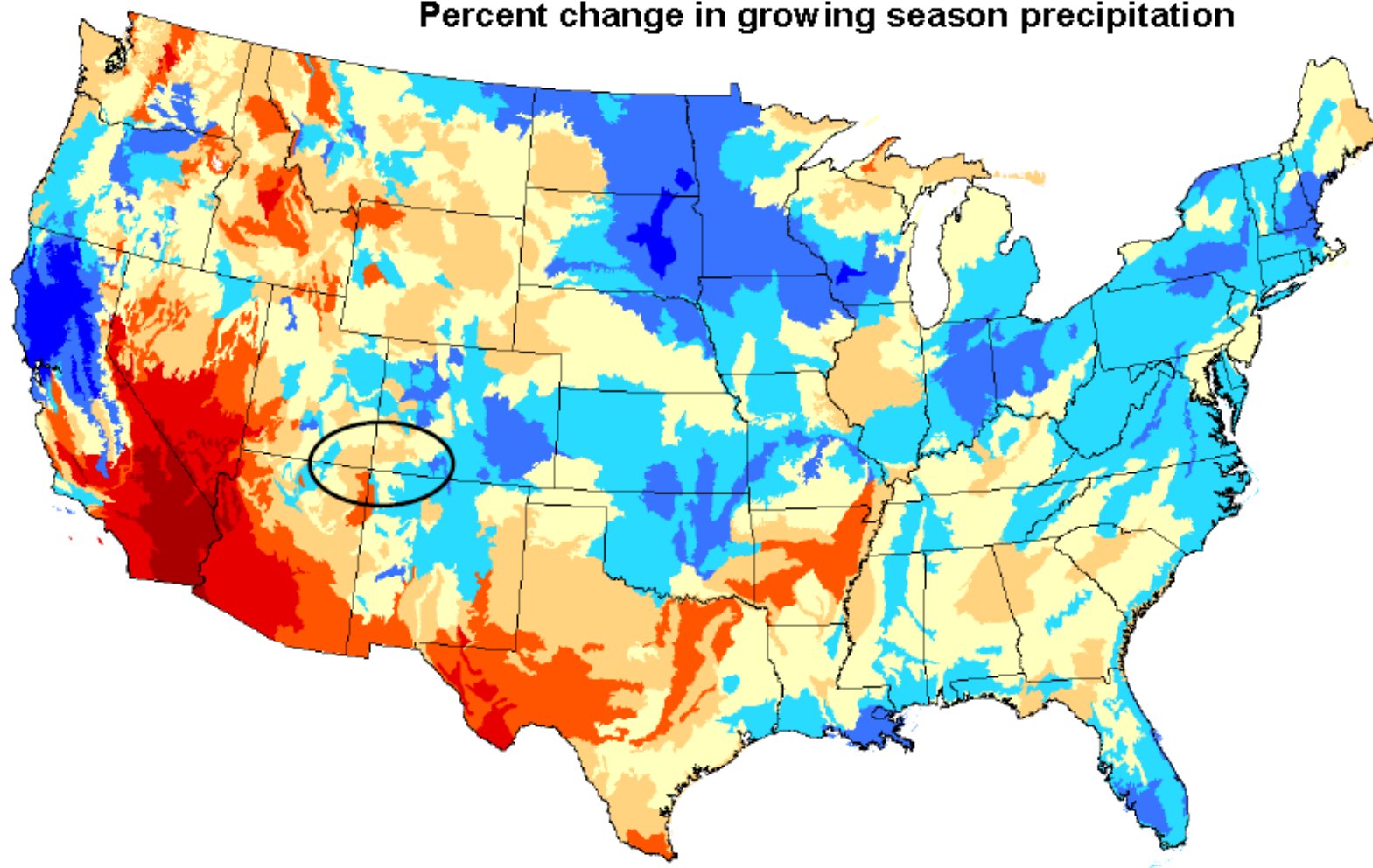
Recent shifts in winter temperature



Change_Winter_Temp



Percent change in growing season precipitation



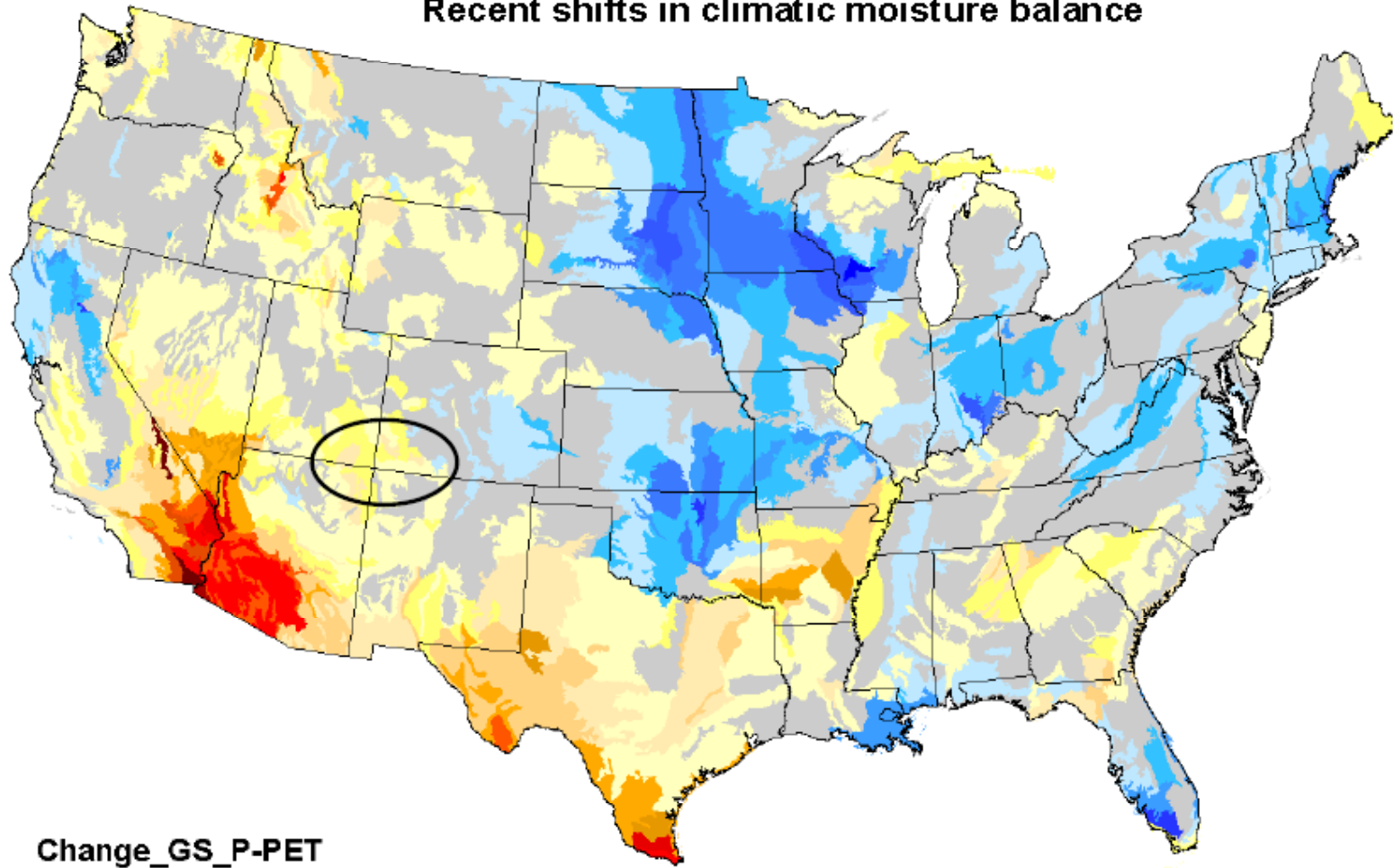
Percent Change Growing Season Precipitation

Subsections GS_CG_P_PT

Dark Red	-45.8 -- -26.4	Red	-26.3 -- -15.0	Light Orange	-6.9 -- -2.1	Yellow	-2.0 -- 1.8	Light Blue	1.9 -- 6.4	Medium Blue	6.5 -- 13.8	Dark Blue	13.9 -- 30.2
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From Dave Cleland, USFS, 2010

Recent shifts in climatic moisture balance



Change_GS_P-PET

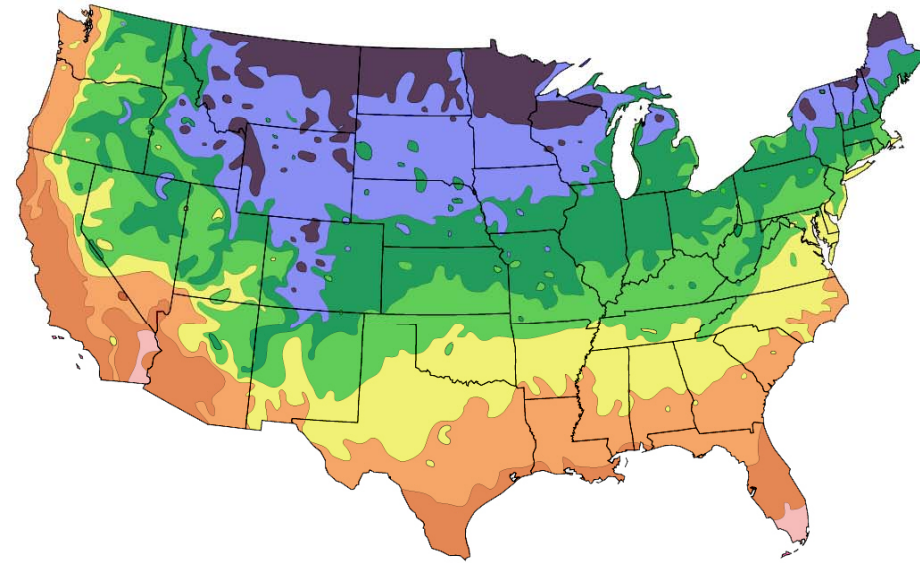
Subsections	-5.4 - -5.0	-3.4 - -3.0	-1.4 - -1.0	0.6 - 1.0	2.6 - 3.0
GS_CG_PPET	-4.9 - -4.5	-2.9 - -2.5	-0.9 - -0.5	1.1 - 1.5	3.1 - 3.5
	-6.4 - -6.0	-4.4 - -4.0	-2.4 - -2.0	-0.4 - 0.0	1.6 - 2.0
	-5.9 - -5.5	-3.9 - -3.5	-1.9 - -1.5	0.1 - 0.5	2.1 - 2.5
				1.1 - 1.5	3.1 - 3.5
				1.6 - 2.0	3.6 - 4.0

From Dave Cleland, USFS, 2010

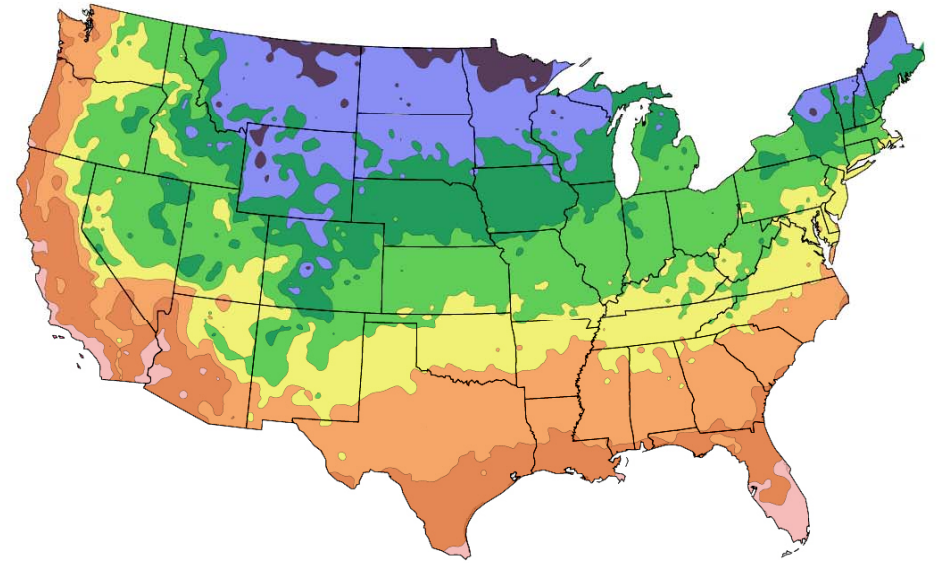
1990 Map

Plant Hardiness Maps

2006 Map

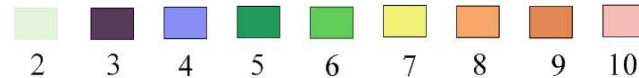


After USDA Plant Hardiness Zone Map, USDA Miscellaneous
Publication No. 1475, Issued January 1990



National Arbor Day Foundation Plant Hardiness Zone Map
published in 2006.

Zone



Responses to warming
temperatures seen in
more than 26,000 physical
and biological systems
around the world.



Montana's Glacier National Park

1910: 150 glaciers; **Today:** 30 glaciers

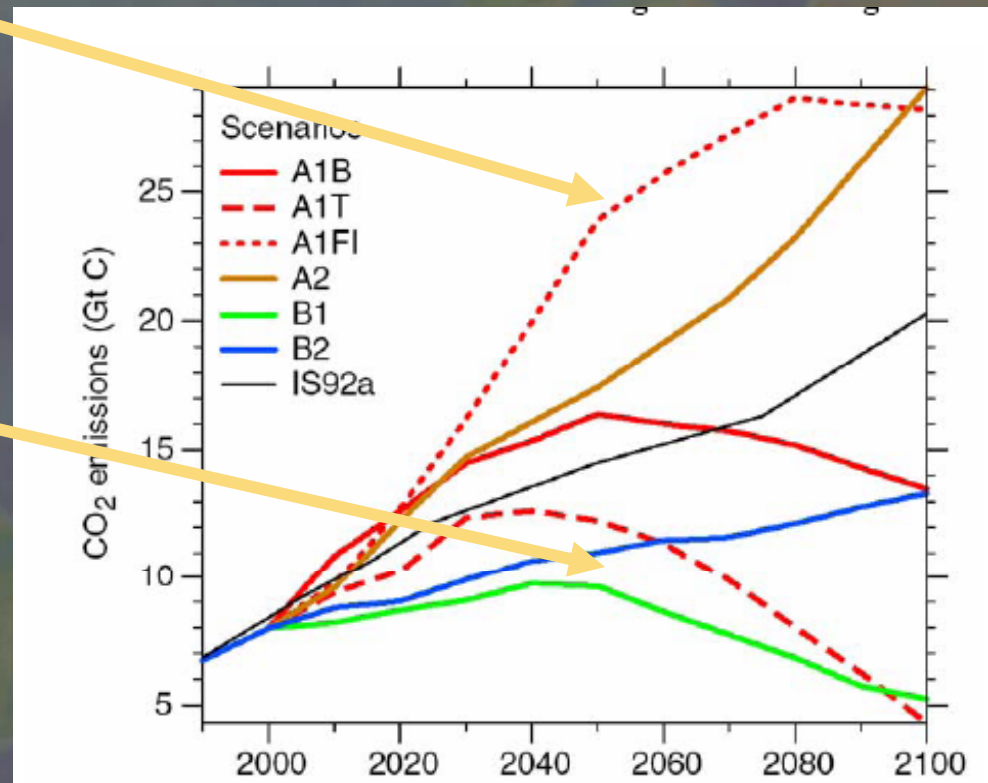


Future effects

Highly tied to the level of CO₂
emissions

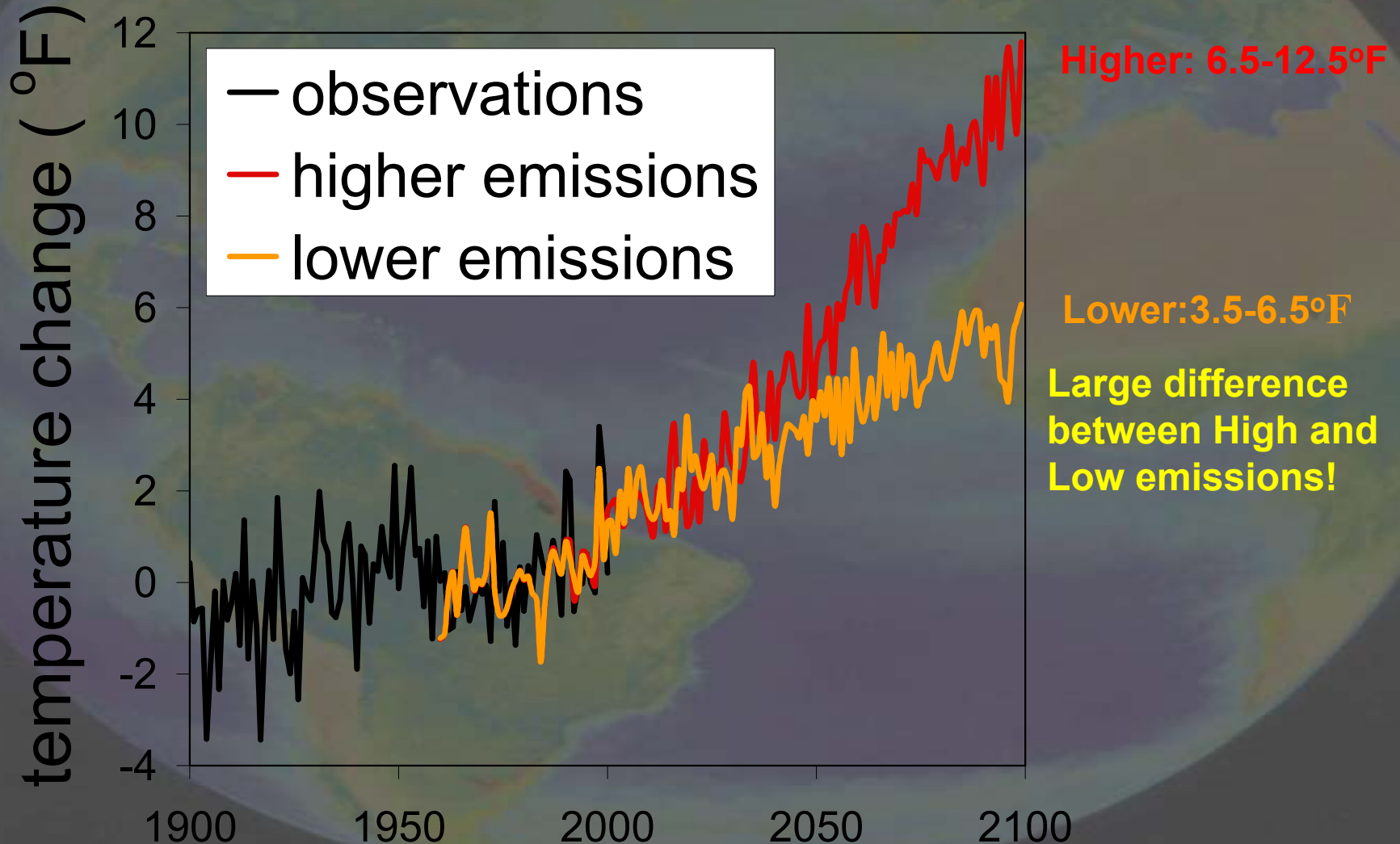
Emissions of CO₂ – range of scenarios over next 100 years

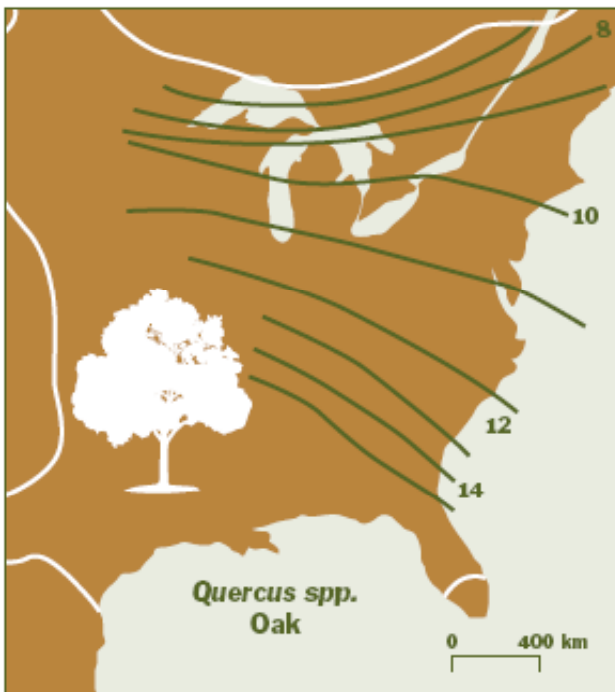
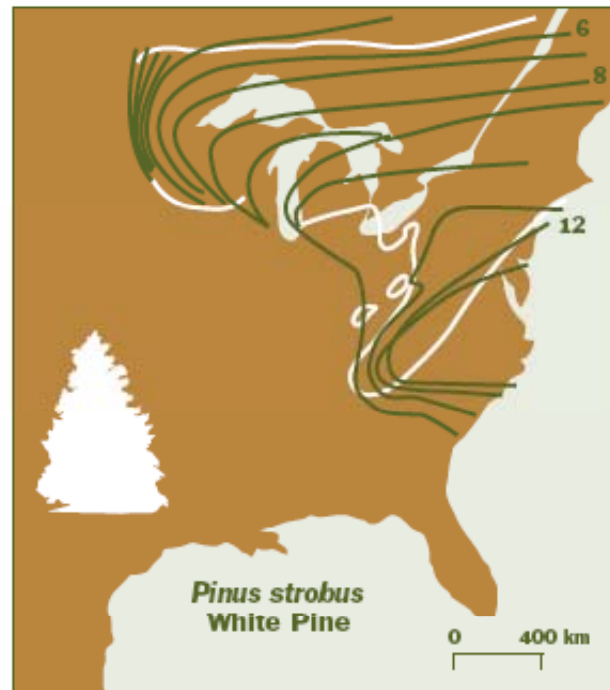
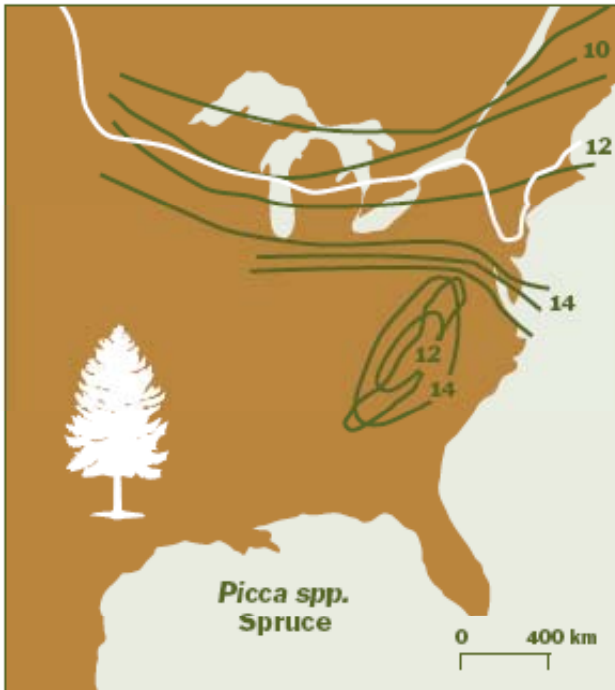
- A1fi (high)-fossil fuel intensive until later century
- B1 (low)-shift to resource efficient technology



Rising Temperatures in E. US

(annual average)

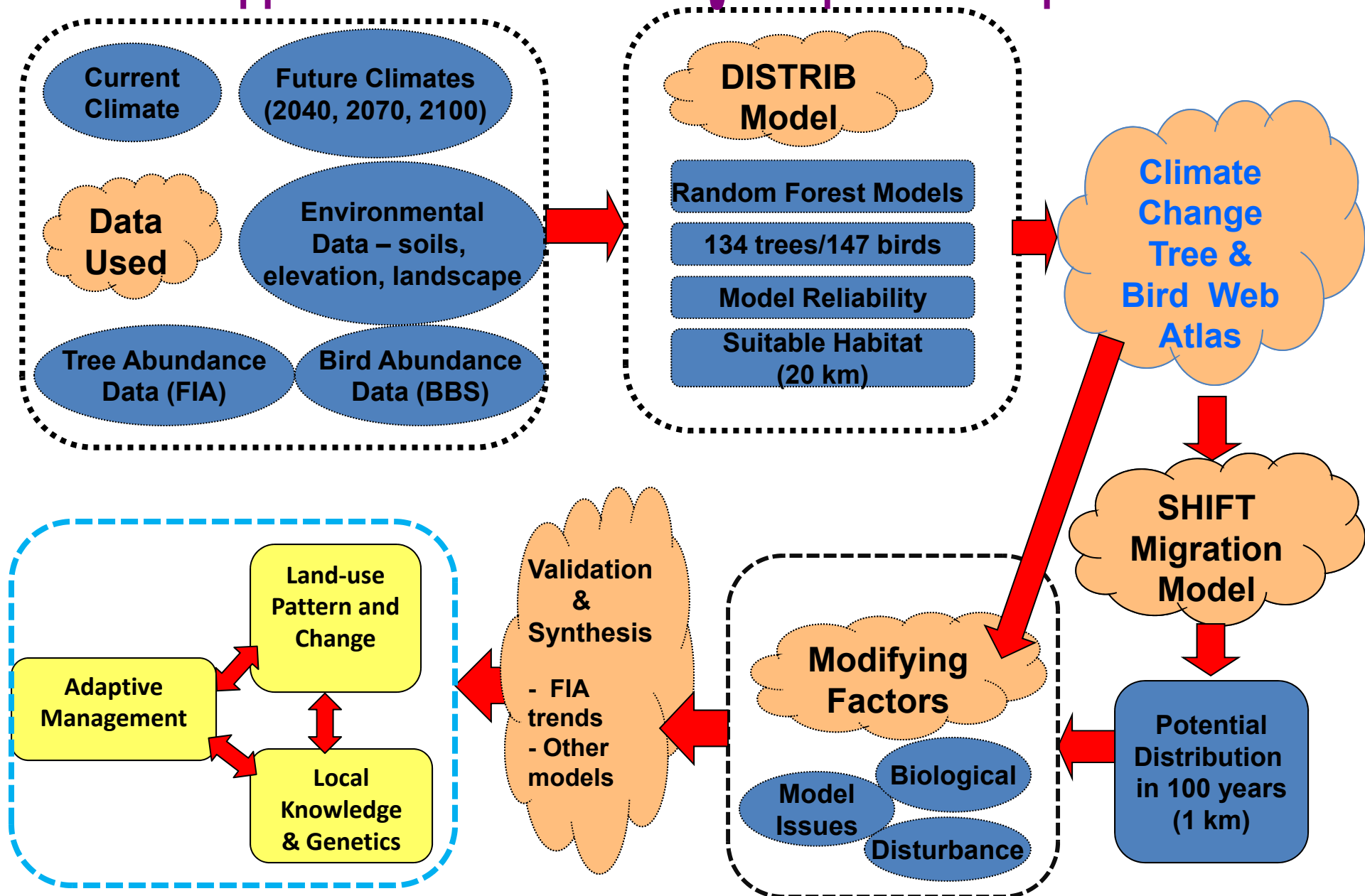




- During the Holocene, which began 10-12k yrs ago, the avg. global temperatures increased by about 2 deg C.
- This warming is at the low end of IPCC, 2007 projections for 2100 !!!

How's present-day vegetation going change with such rapid climate change + human-landuse disturbance ???

Our Approach: Climate Change Impacts on Species

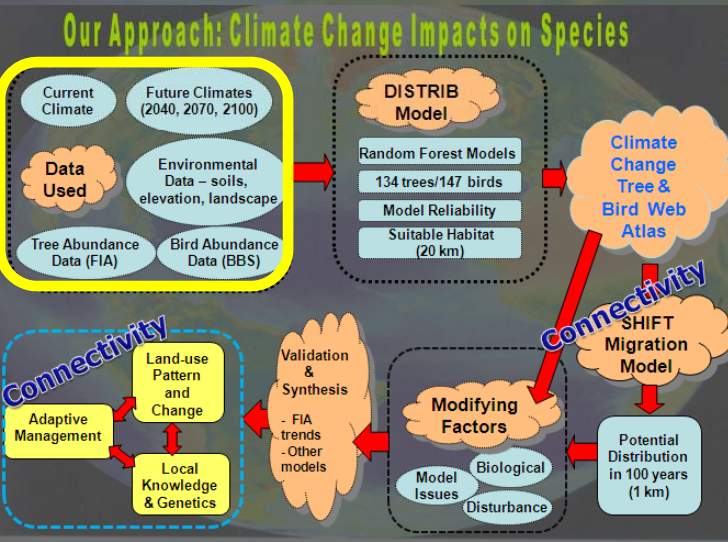


Assembling responses

Forest Inventory and Analysis (FIA)

- 37 states east of 100th meridian
- 134 tree taxa
- 103,488 plots
- 2,938,518 tree records

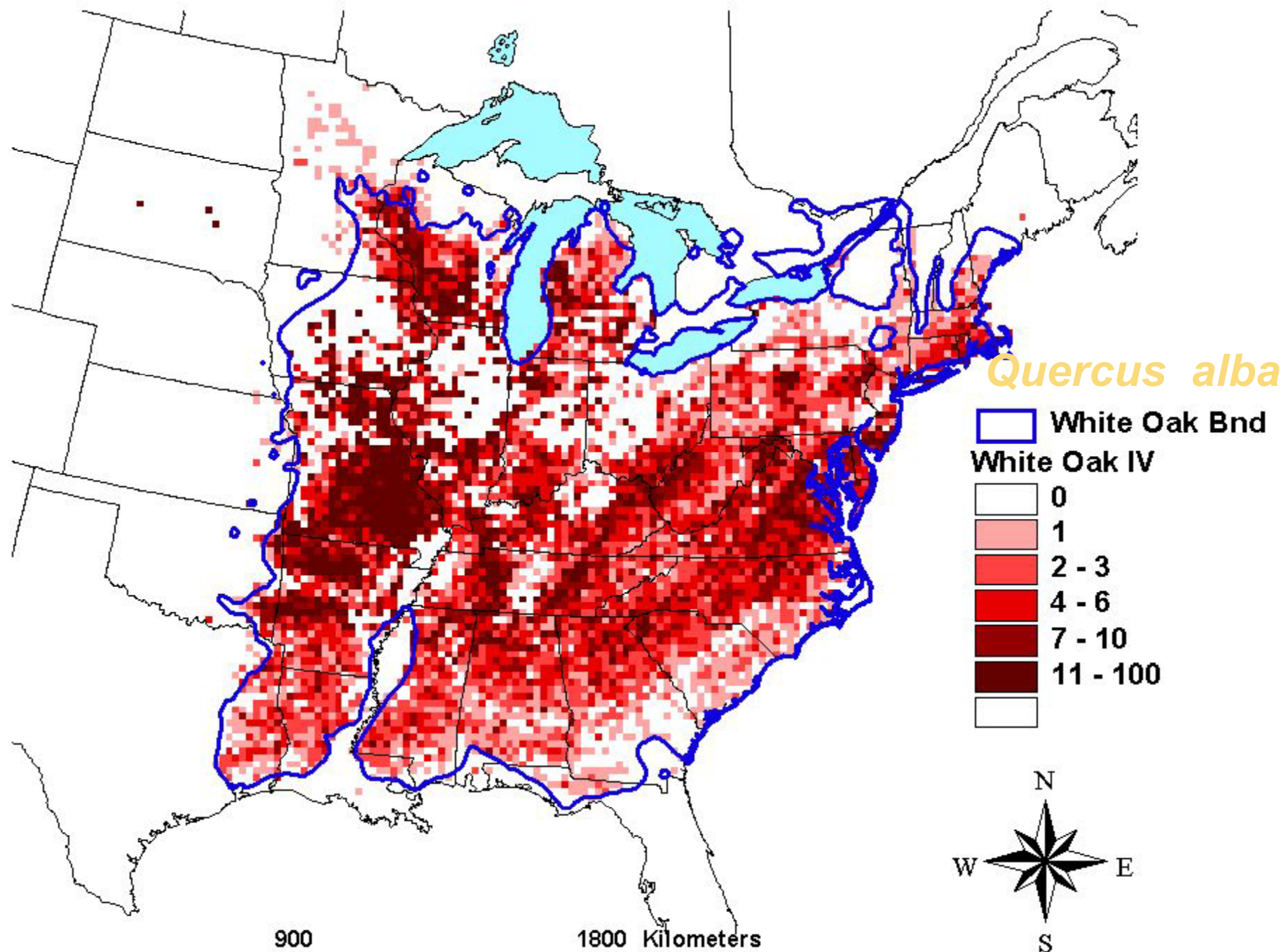
- Extract FIA plot data by State
- Calculate Importance Value (IV) for each species (basal area & no. of stems)
- Aggregate plots to 20x20 km grids (approx. 10,000 cells for eastern US)



OUTPUT

Importance Values (Abundances) (IV)
for 134 tree species by 20 km cell
(Range of IV: 0-100)

White Oak Importance Value and Little's Bnd



Tree species predictors

38 Predictors

- 7 Climate
- 9 Soil Classes
- 13 Soil Properties
- 5 Elevation
- 3 Land-use
- 1 Fragmentation Index

Current

GCMs, 2100

HadCM3

GFDL

PCM

**IPCC
Carbon
Emission
Scenarios**

A1fi (High)

B1 (Low)

A1fi + HadCM3 (HadHi) – Most extreme

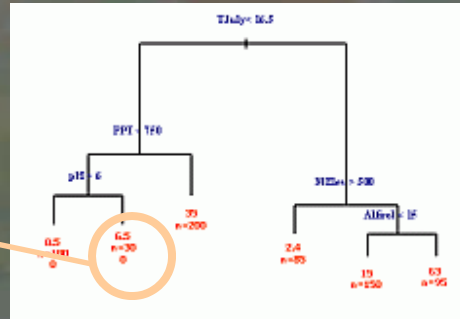
B1 + PCM (PCMLo)– Least extreme

Had+GFDL+PCM/A1fi – Ave Hi

Had+GFDL+PCM/B1 – Ave Lo

Tri-Model Approach

Prasad, A. M., L. R.
Newer classificat
techniques: bagging
for ecological pre
Ecosystems 9:181



*Helps understand
relationships, and
map drivers*

$T_{July} < 16.5$ &
 $PPT < 750$ &
 $PH \leq 6$

Single Decision Tree

2/3 random sampling of observations for each tree



30
decision
trees

Bagging Trees

*use 30 decision trees to assess variability among individual tree models
- a measure of model reliability*

Model Reliability: ● High ● Medium ● Low

Random sampling + randomized subset of predictors for each tree



1000
decision
trees

Random Forests

best for prediction without overfitting

Important!

- With these DISTRIB models, we are predicting potential **suitable habitat** by year 2100. We are NOT predicting where the species will be at that time, as great lag times are involved in tree species migrations.
- We attempt to get at the potential movements over the next 100 yrs with the SHIFT model.

You are here: [NRS Home](#) / [Tools & Applications](#) / [Climate Change Atlas](#) / [Tree Atlas](#)

Climate Change Tree Atlas (A Spatial Database of 134 Tree Species of the Eastern USA)

Anantha M Prasad, Louis R Iverson, Steve Matthews, Matt Peters

NRS-4151, USDA Forest Service, Northern Research Station, Delaware, Ohio

[Atlas Background](#)
[What's New](#)
[Citations](#)
[Credits](#)
[Atlas Help](#)
[Other Links \(DropDownMenu\)](#)

Table of 134 Tree Species:

(Click Table-Header-Link to Sort by that Column - Ascending/Descending)

Reliability	Spp. #	Common Name	Scientific Name
	951	American basswood	<i>Tilia americana</i>
	531	American beech	<i>Fagus grandifolia</i>
	421	American chestnut	<i>Castanea dentata</i>
	972	American elm	<i>Ulmus americana</i>
	591	American holly	<i>Ilex opaca</i>
	391	American hornbeam: musclewood	<i>Carpinus caroliniana</i>
	935	American mountain-ash	<i>Sorbus americana</i>
	43	Atlantic white-cedar	<i>Chamaecyparis thyoides</i>

Model Reliability: High Medium Low

134 Species Combined/Compared

Combined Species
Outputs

Summary of
Predictors

Species Information

Family: Aceraceae

Guild: persistent, slow-growing understory tolerant

Functional Lifeform: large deciduous tree

[Life History and Disturbance Response](#)

External Species Links

Silvics Manual: [Click here for sugar maple](#)

Plant Photos: [Photos of the tree in USDA Plants Database](#)

Google Earth: [View current and modelled sugar maple](#)

Research Products (IMPORTANT: Read this first)

Current Distribution

Abundance & Little's
Range Maps

HotSpot
Maps

Niche
Maps

Geographic Predictors
Map

Statistics, Tables &
Interpretations

Modelled Future Habitat

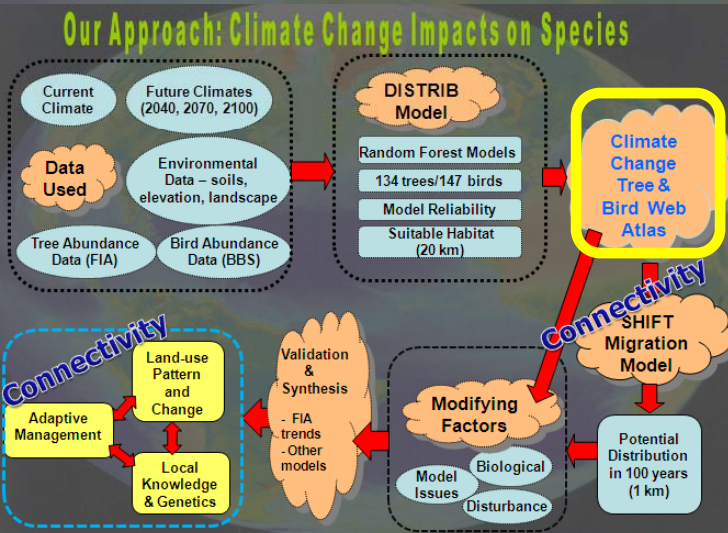
Abundance Change
Maps

Summary
Change Maps

HotSpot Change
Maps

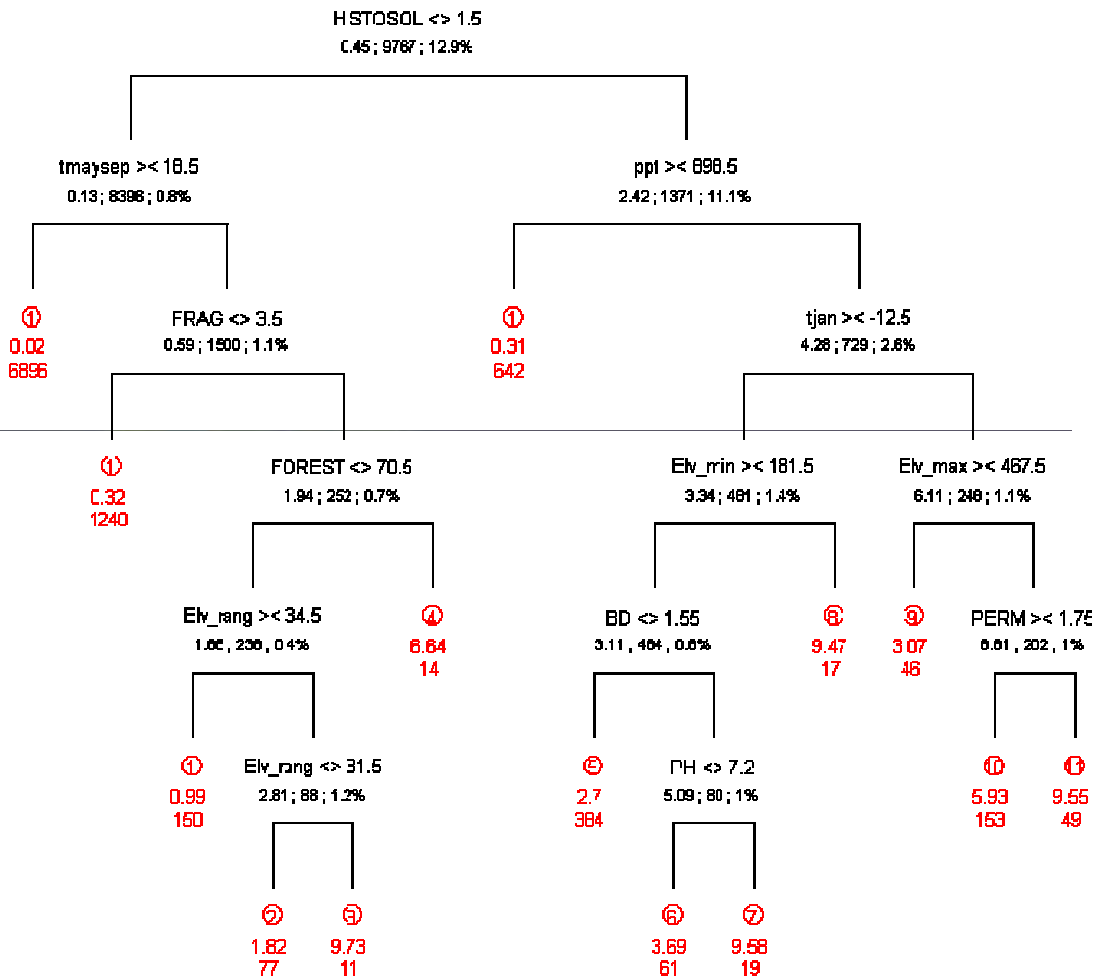
Mean Center/Distribution
Ellipse Maps

Statistics, Tables &
Interpretations

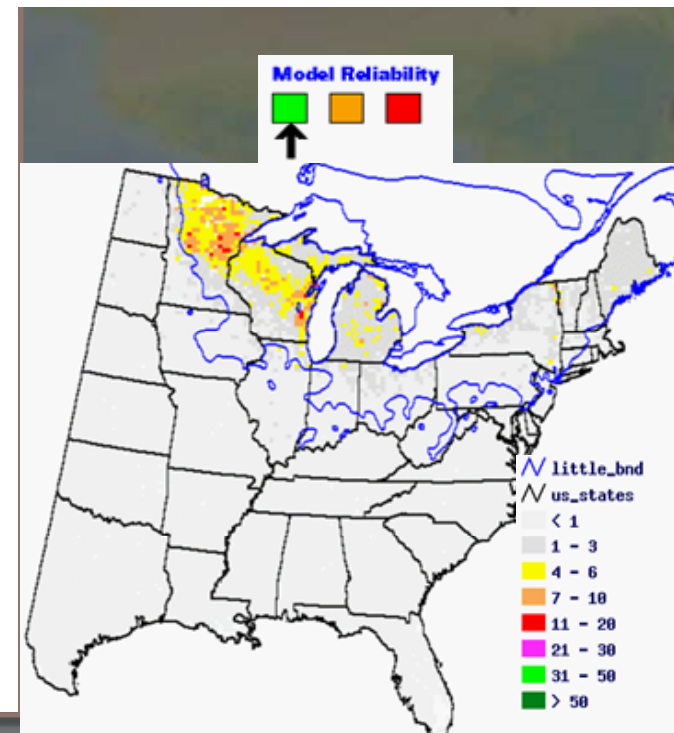
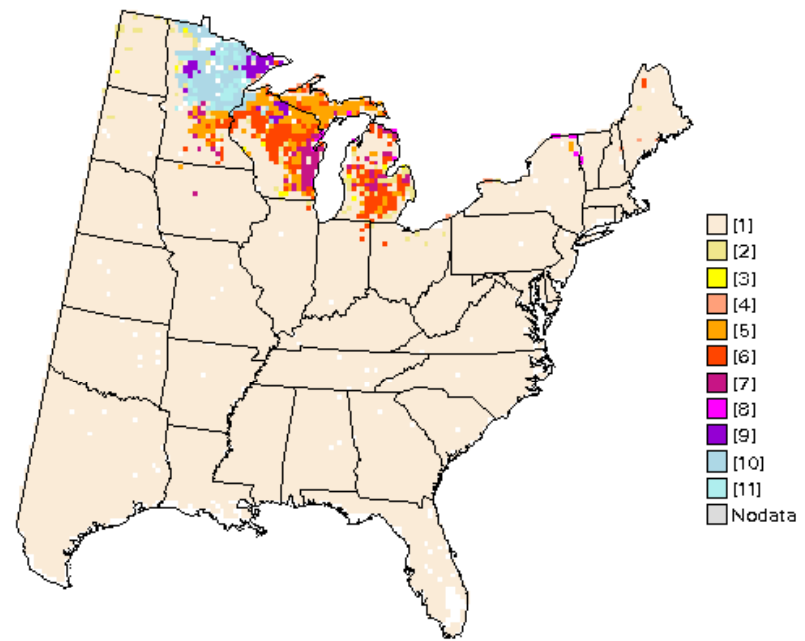


<http://www.nrs.fs.fed.us/atlas>

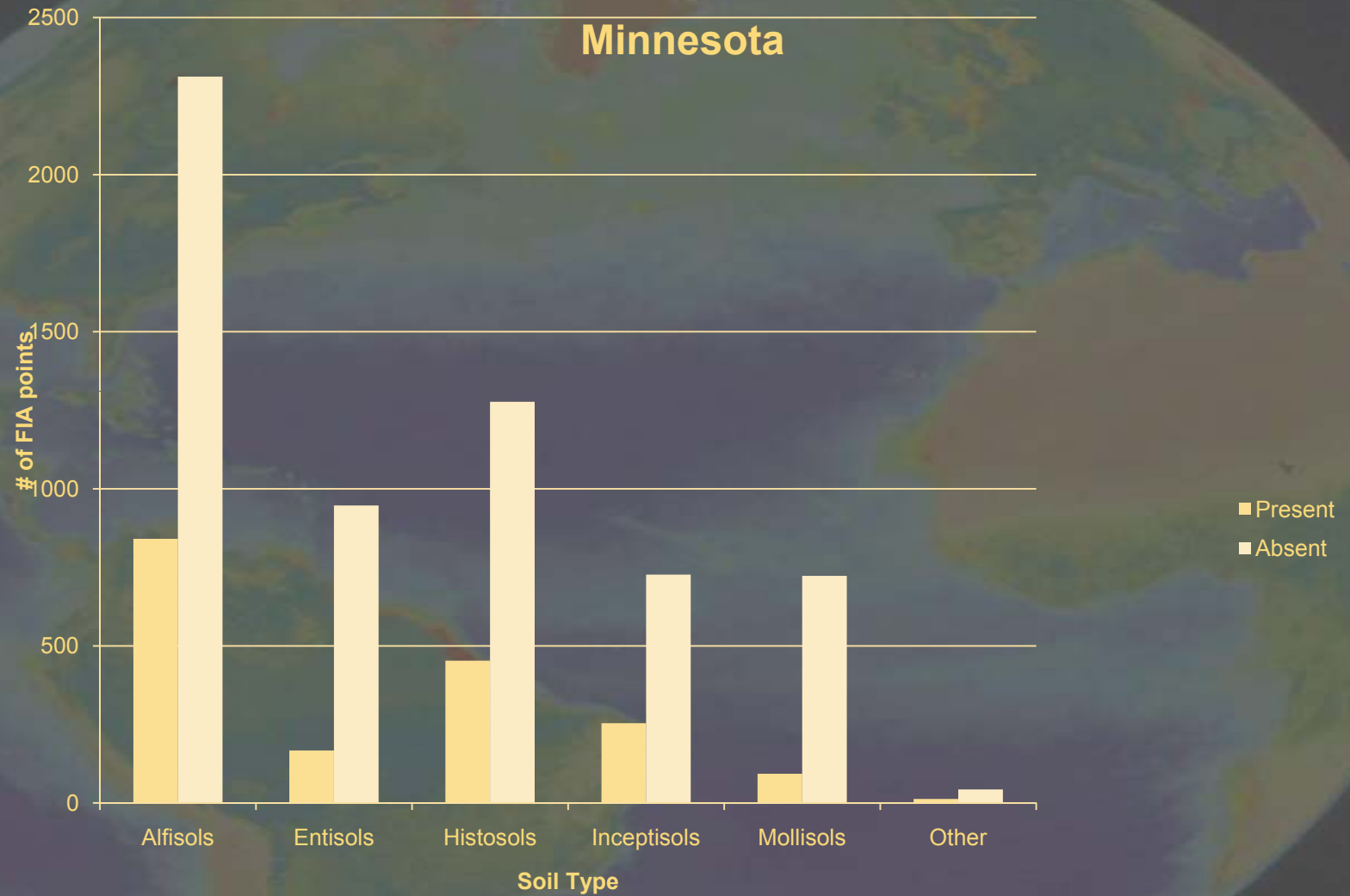
Black Ash



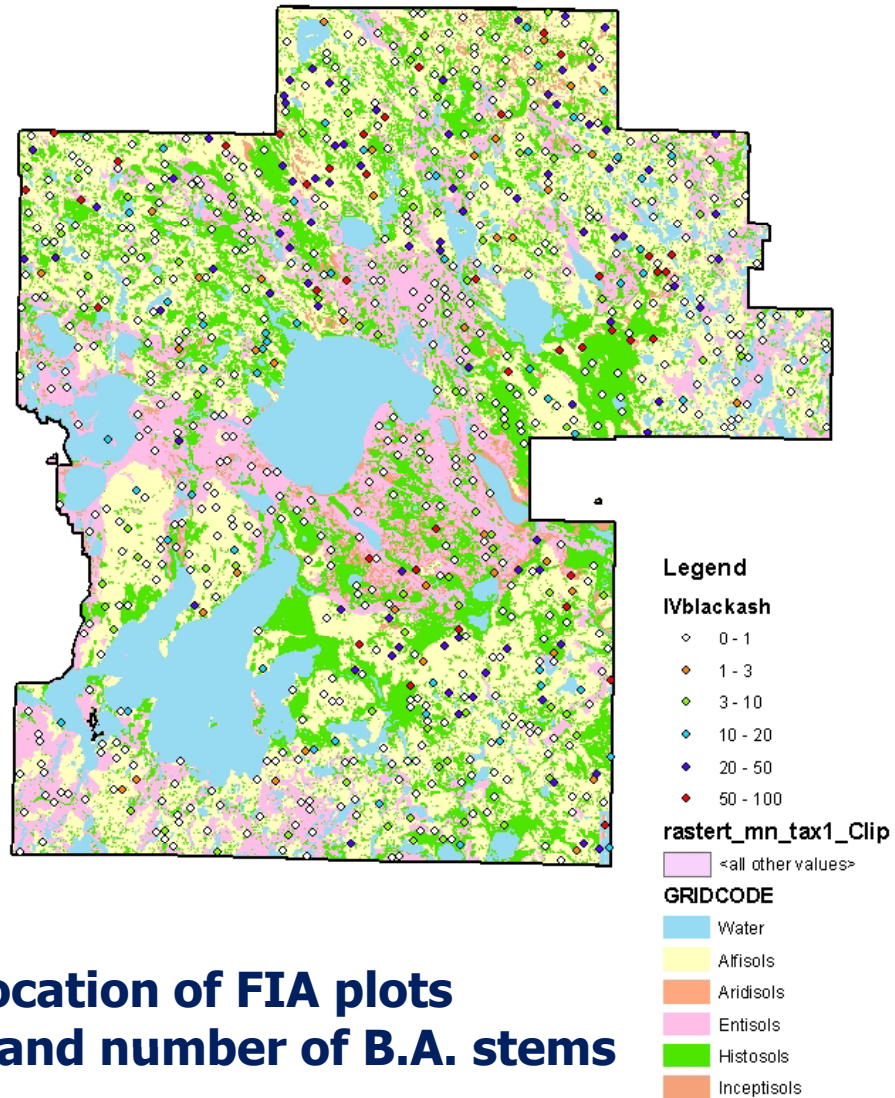
Total deviance explained = 36.1 %



Number of MN FIA Plots with Black Ash Present

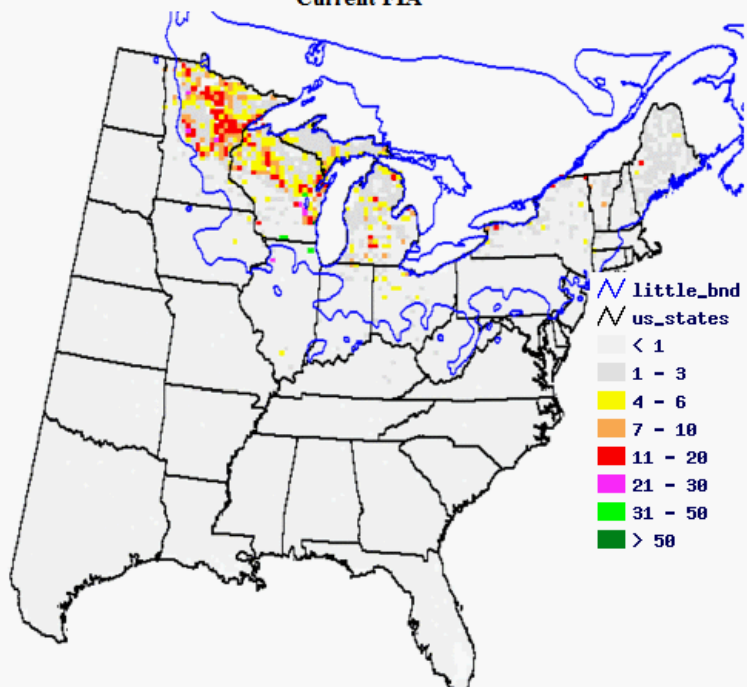


Chippewa National Forest

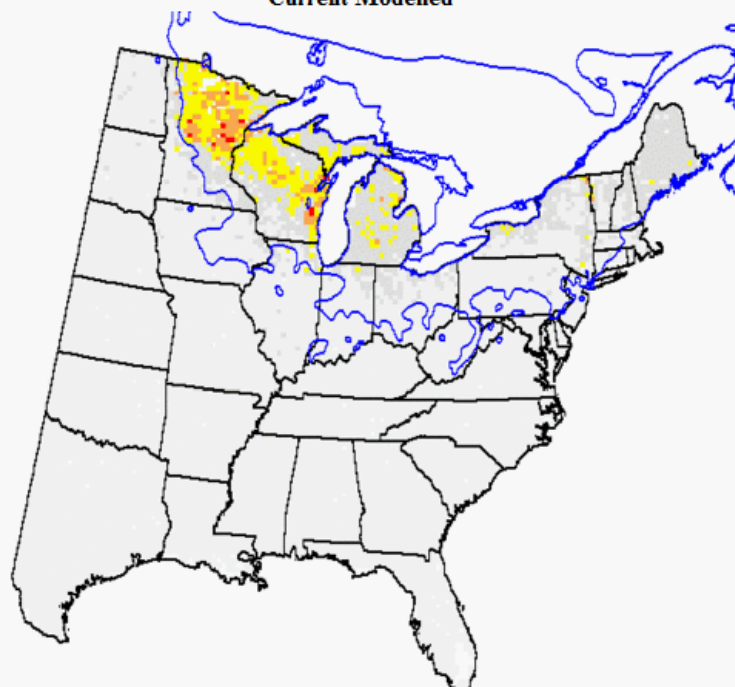


**Location of FIA plots
and number of B.A. stems**

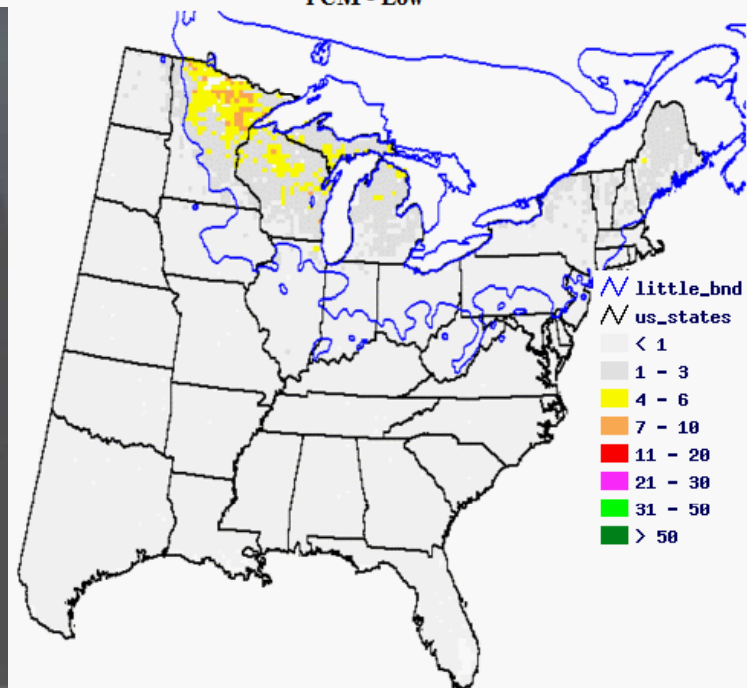
Current FIA



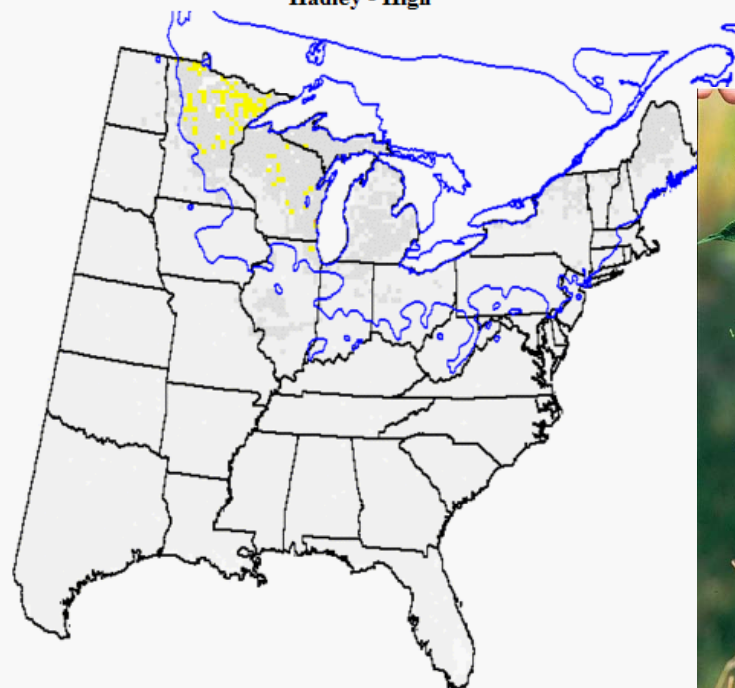
Current Modelled



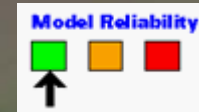
PCM - Low



Hadley - High

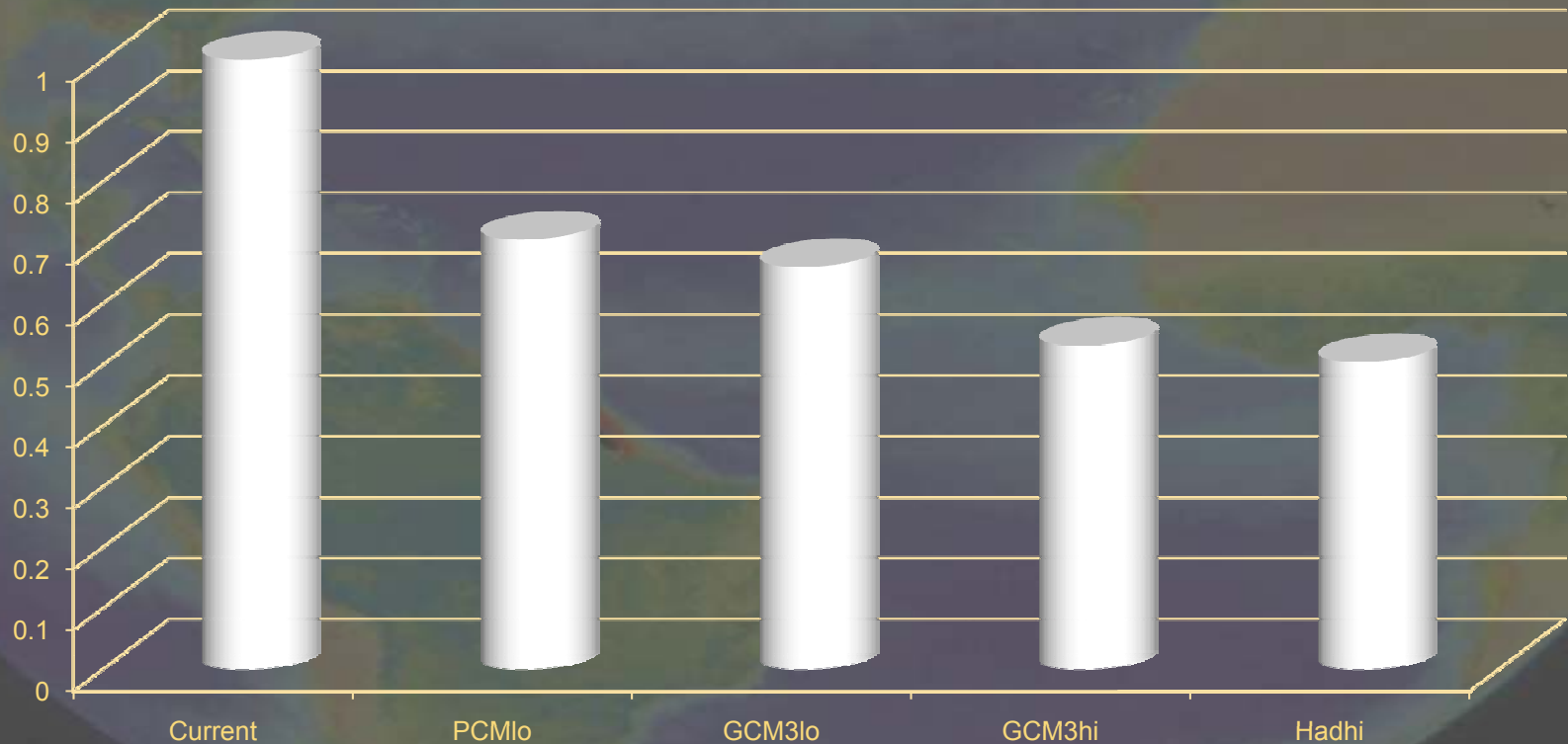


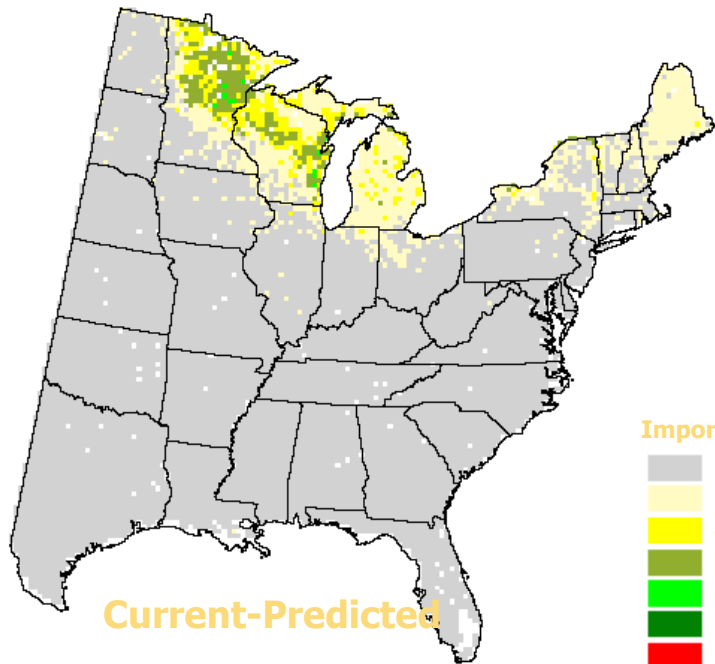
Black Ash



Black ash habitat would decline by 2100

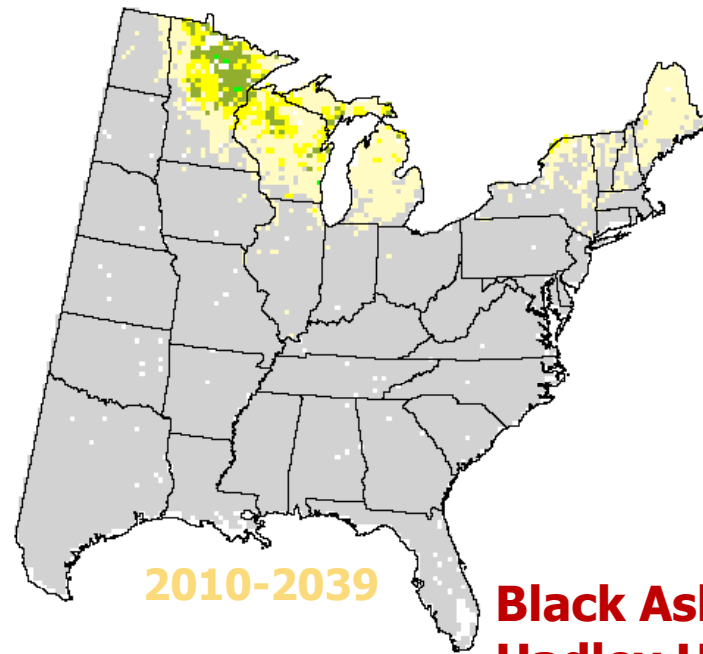
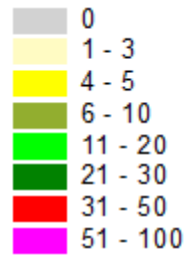
**Ratio of Suitable Habitat in Future to Now
by Increasingly Harsh Scenario**





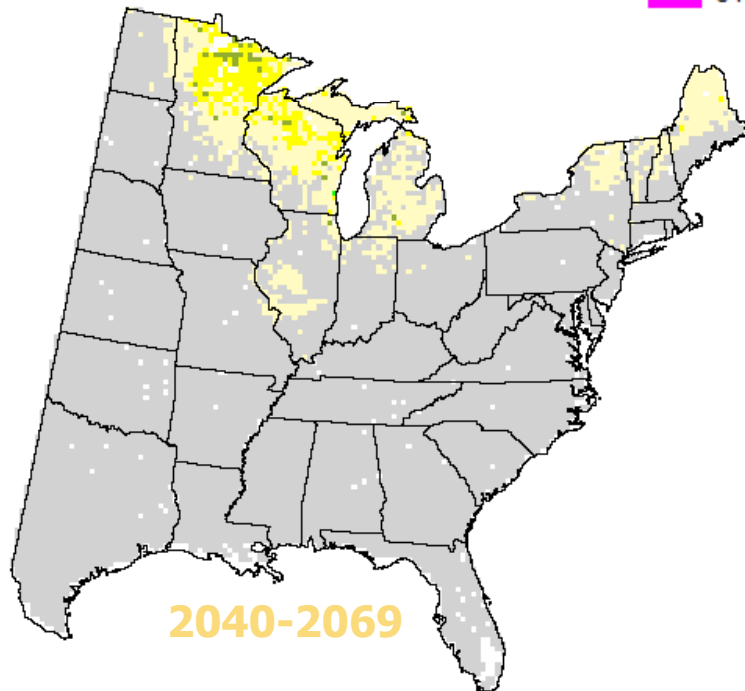
Current-Predicted

Importance Value

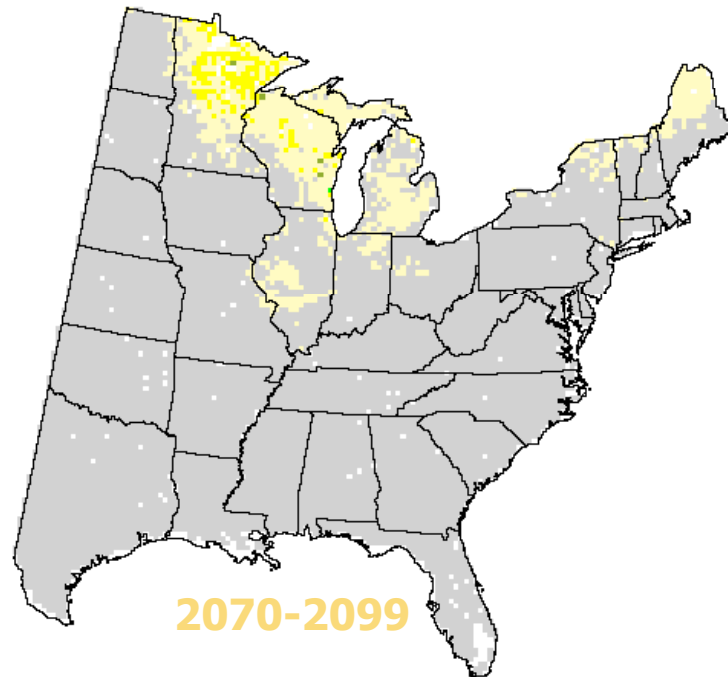


2010-2039

**Black Ash
Hadley High**

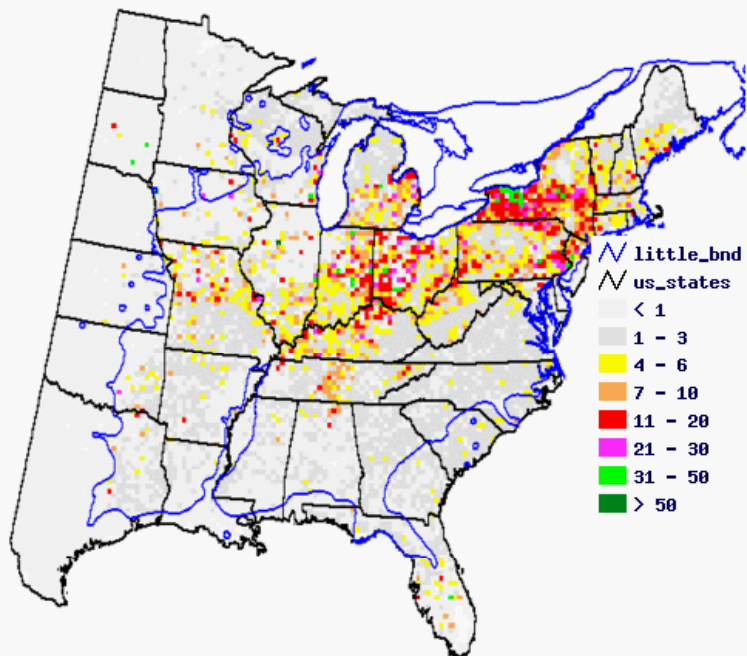


2040-2069

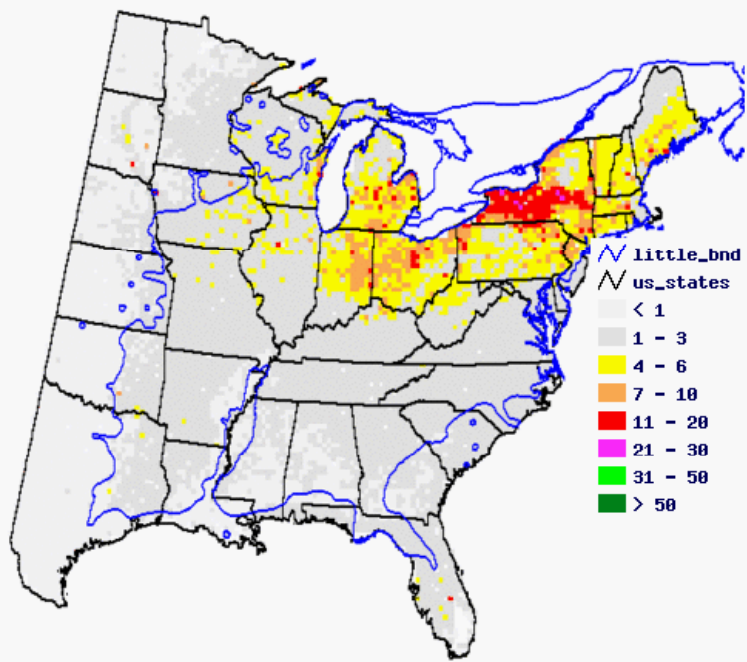


2070-2099

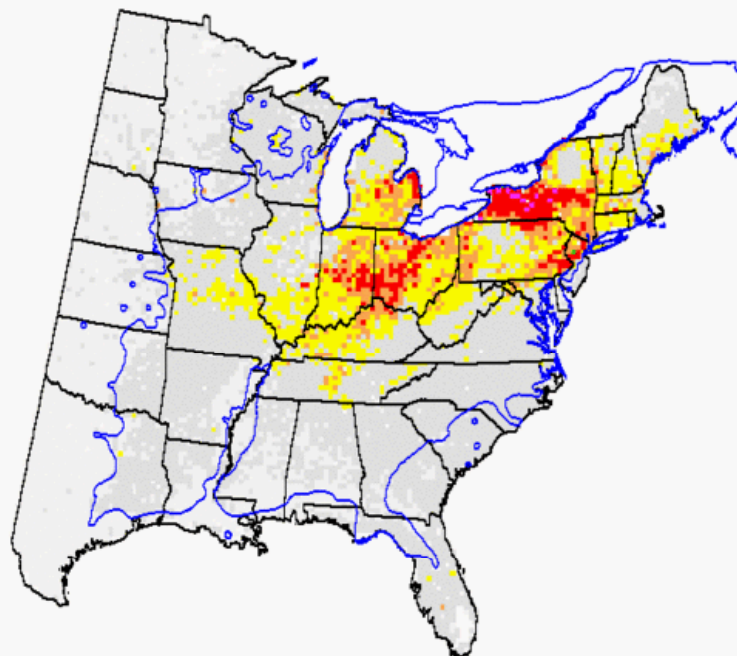
Current FIA



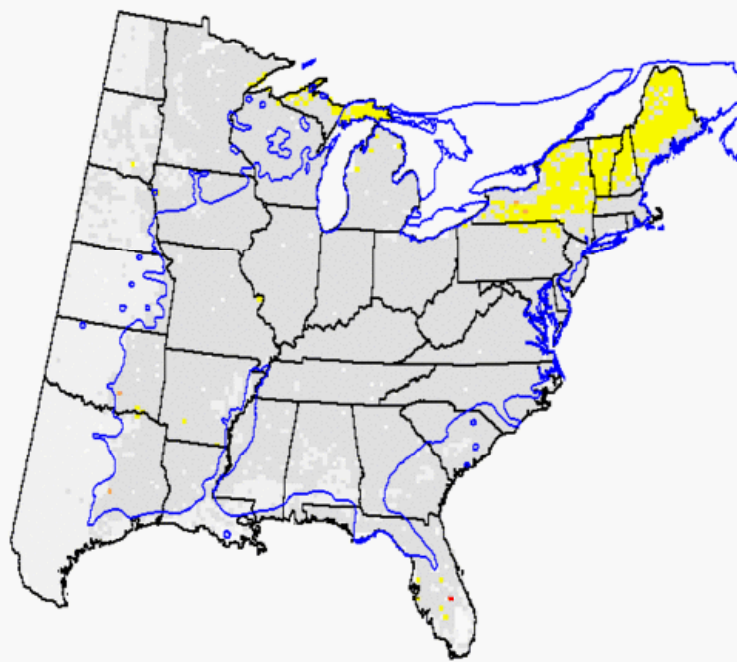
PCM - Low



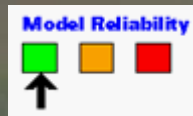
Current Modelled

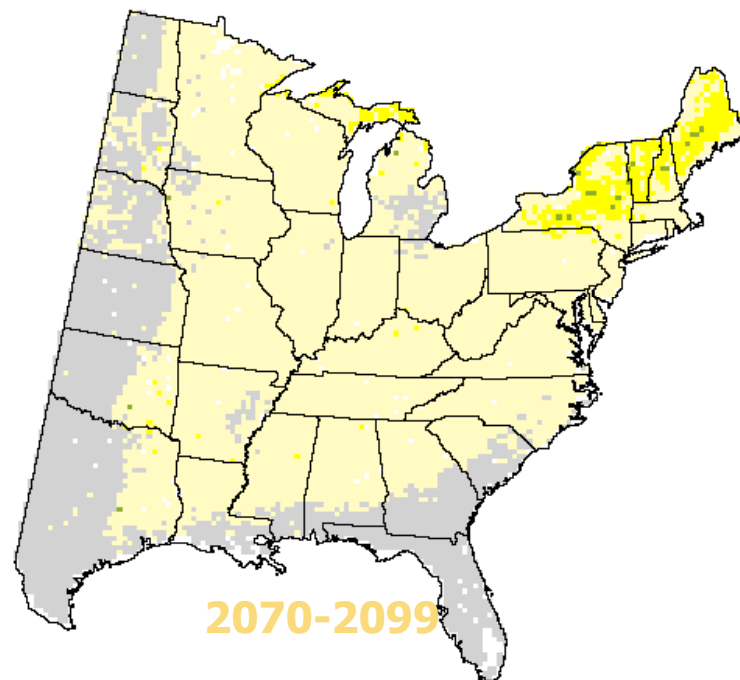
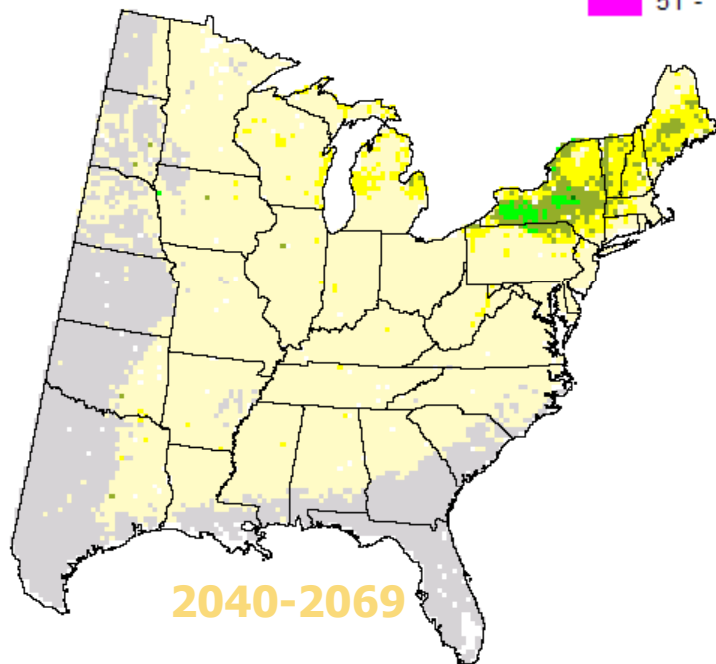
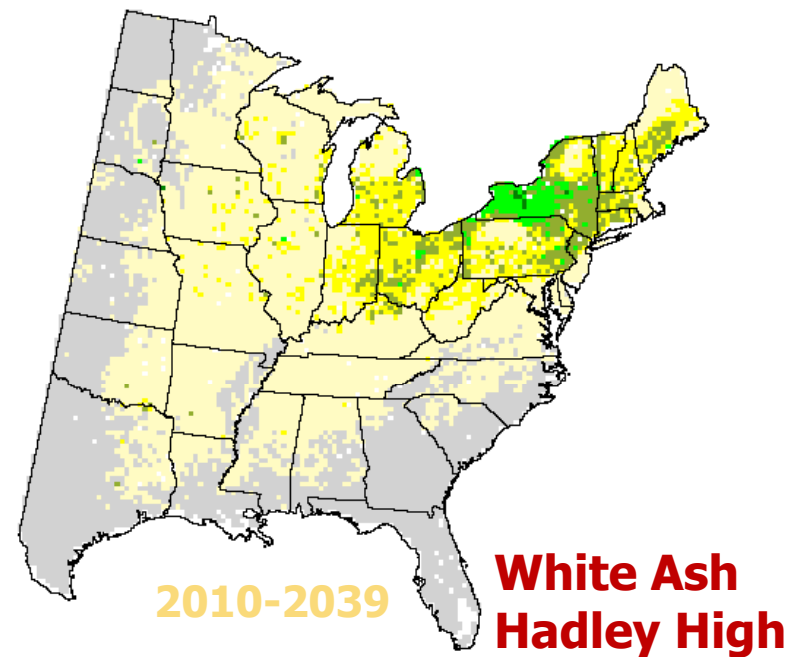
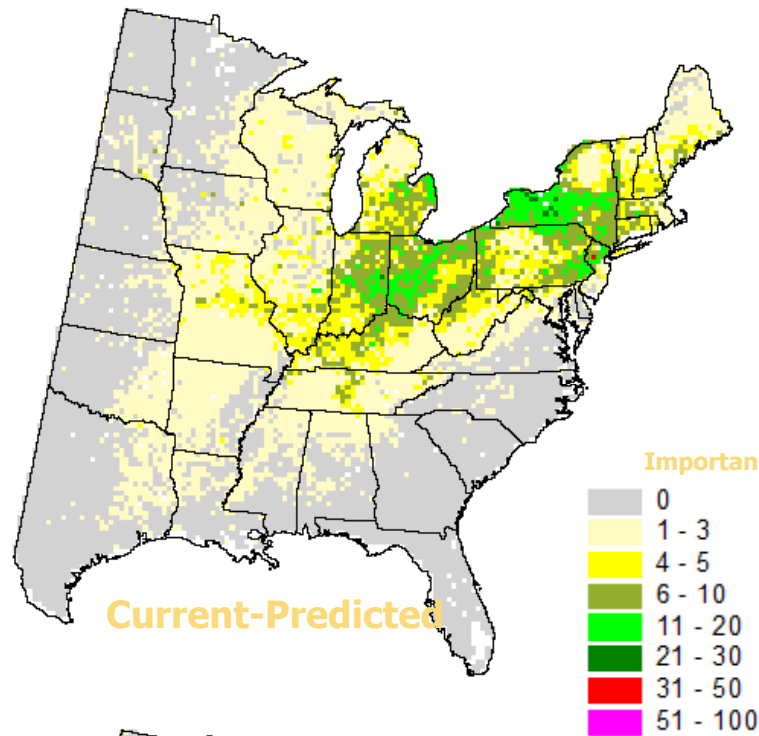


Hadley - High

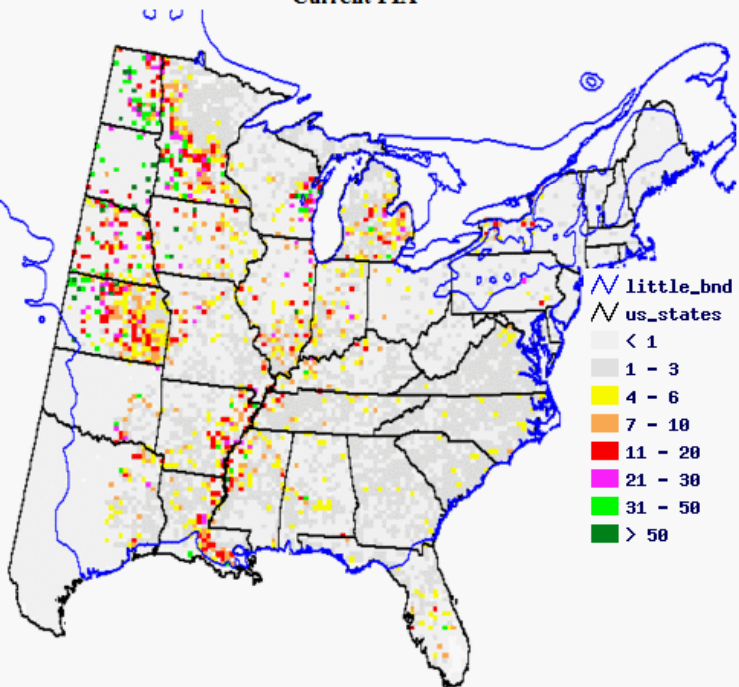


White Ash

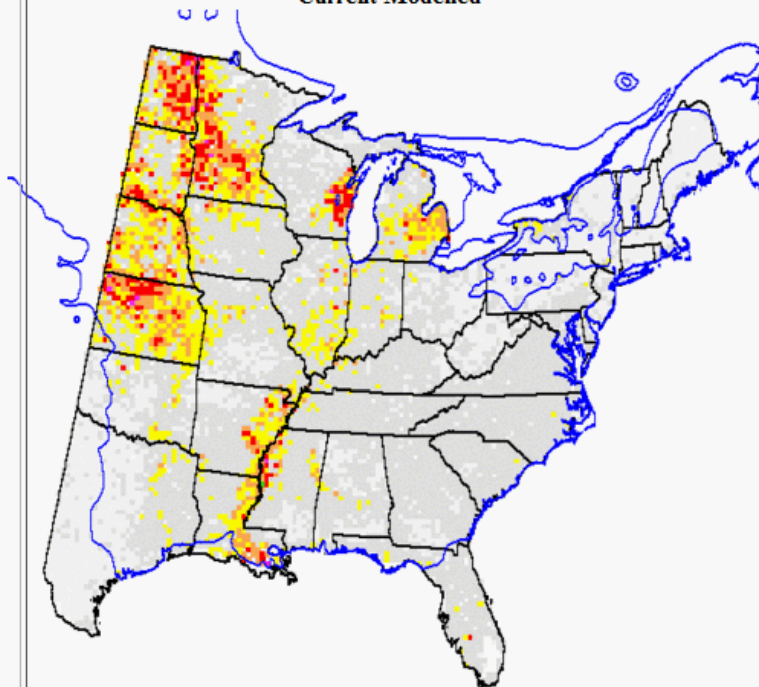




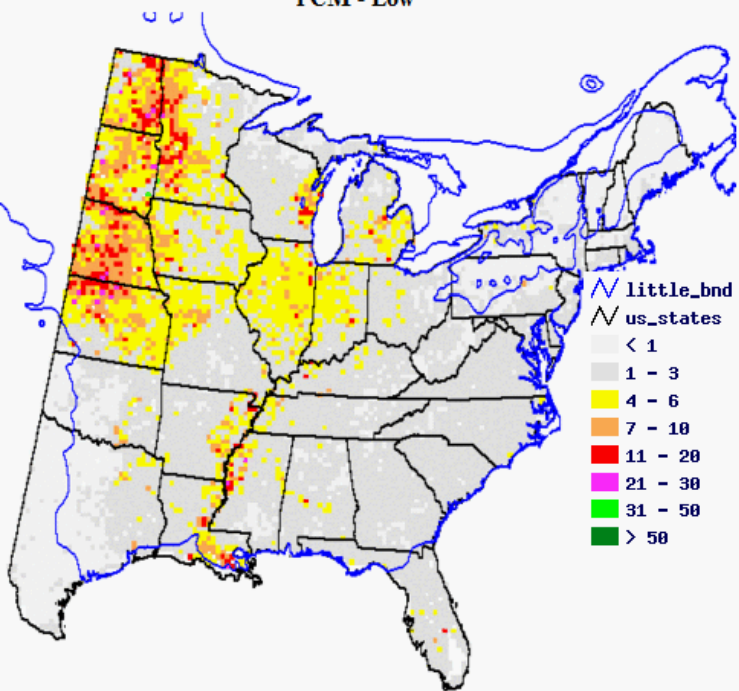
Current FIA



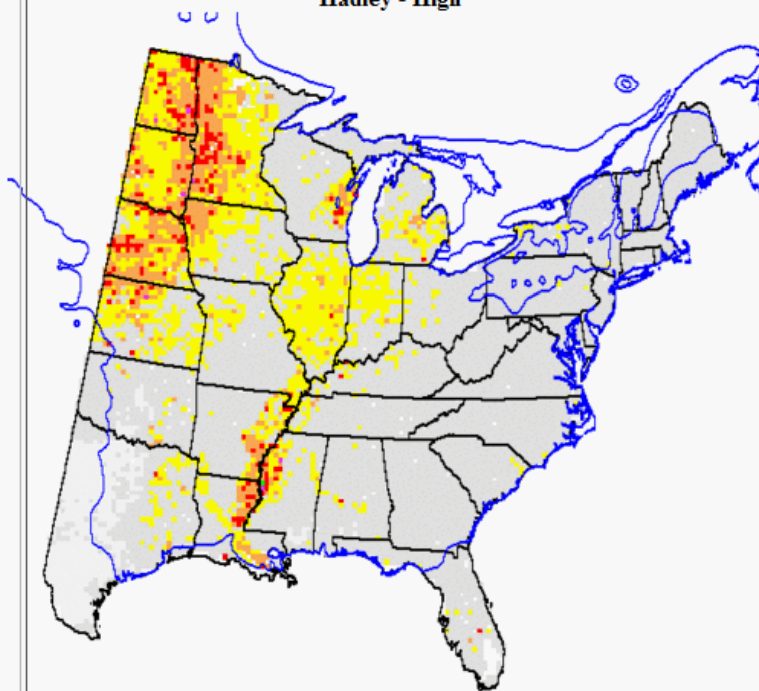
Current Modelled



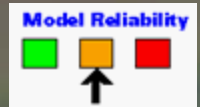
PCM - Low



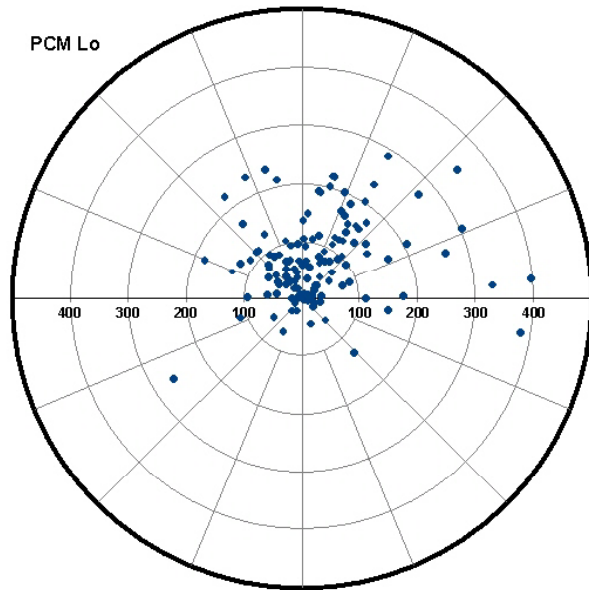
Hadley - High



Green Ash

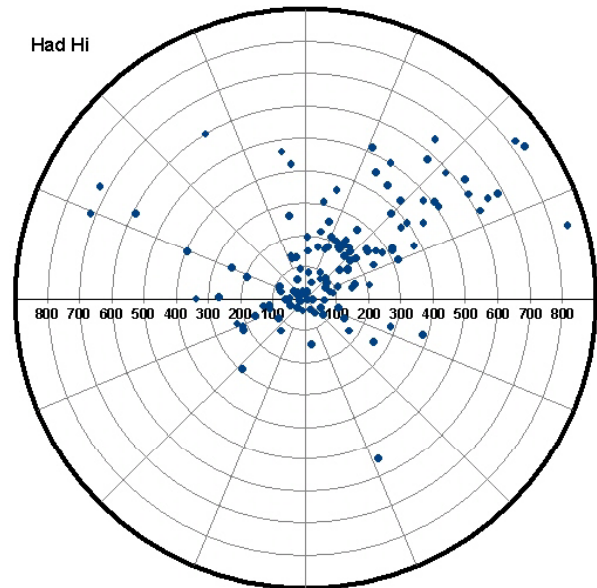


Mean Center Potential Movement



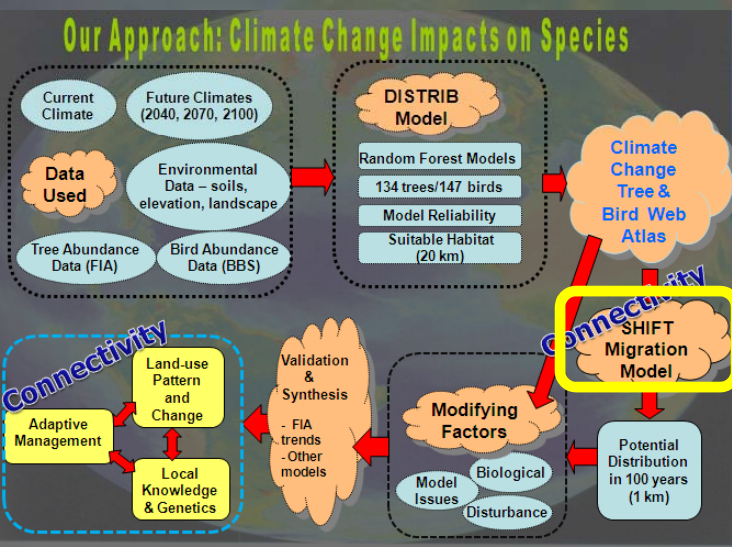
- Two points:**
- 1. Emission levels make big difference**
 - 2. Species will change individually**

**Direction and
distance (km) movement**



Lessons Learned

Separate the discussion of potential changes in suitable habitat from that of potential species range changes within a certain time frame.



**RandomForest based
Statistical Model
(potential suitable
habitat)**

DISTRIB

**Current
Climate**

**Future
Climate
(Hadley, PCM, GFDL)**

**Modelled
Current
IV**

**Modelled
Future
IVs**

**Environmental
Variables**

FIA Data

Calculate IV

**Spatially explicit
cell-based Model
(colonization probability)**

SHIFT

**Species
Range Maps**

**Smoothed
IV**

**100yr
Colonization
Probabilities**

**Percent
Forest**

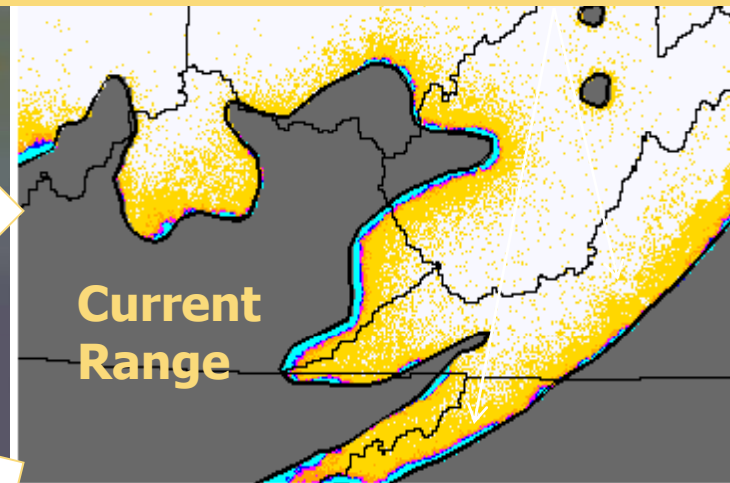
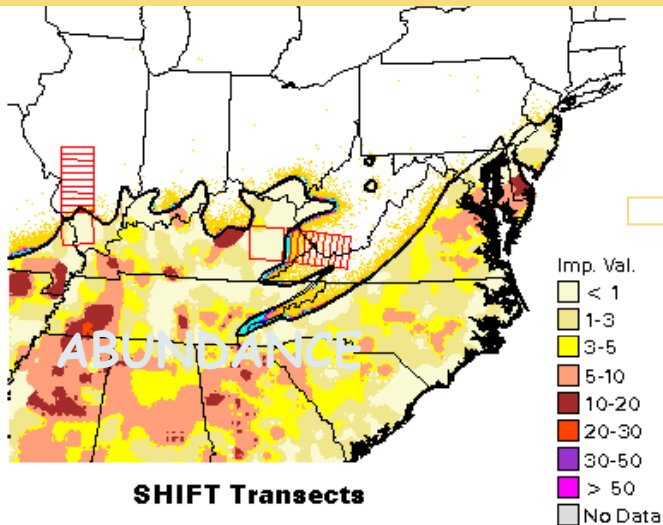
DISTRIB-SHIFT

Potential Distribution after 100 Years

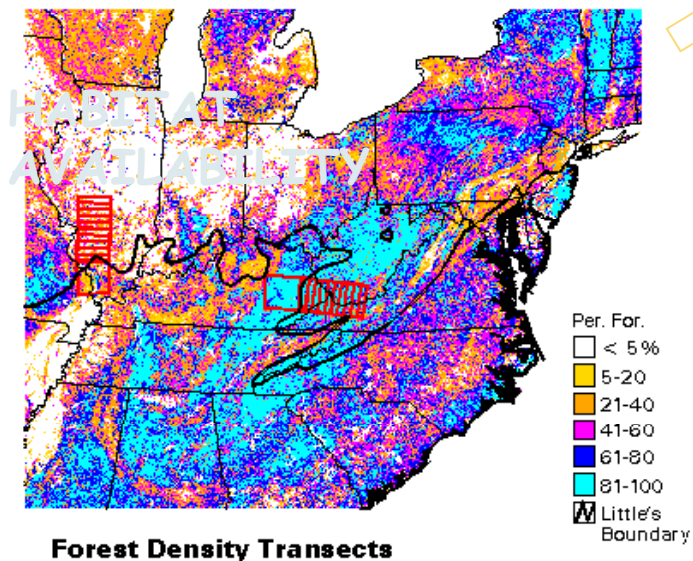
How much of the new suitable habitat might get colonized in 100 years?

Quercus falcata var. *falcata*

Probability of colonization, 0-100%, 100 yrs



Zoomed SHIFT



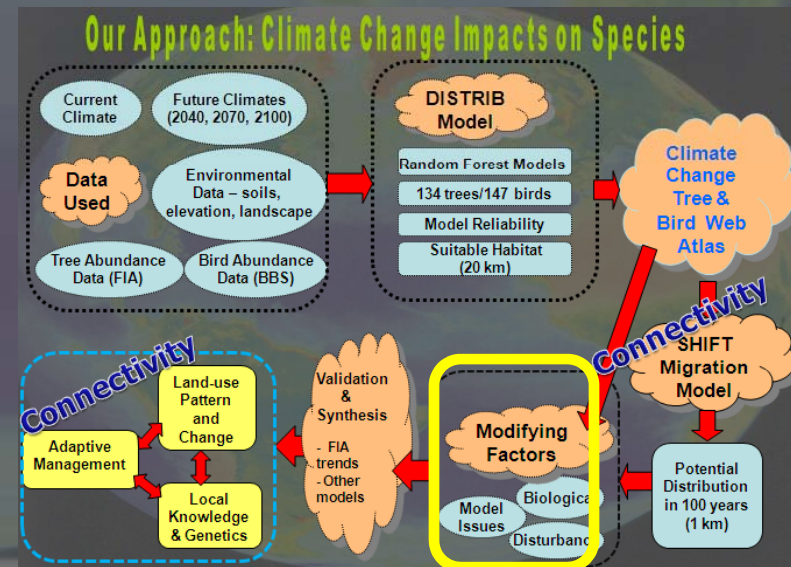
- For 5 species, less than 15% of new habitat would have much chance of getting colonized

- Large lag effect – suitable habitat changes much faster than species can migrate

Lessons Learned

Consider variations in disturbance, biology, and model issues on each modeled species.

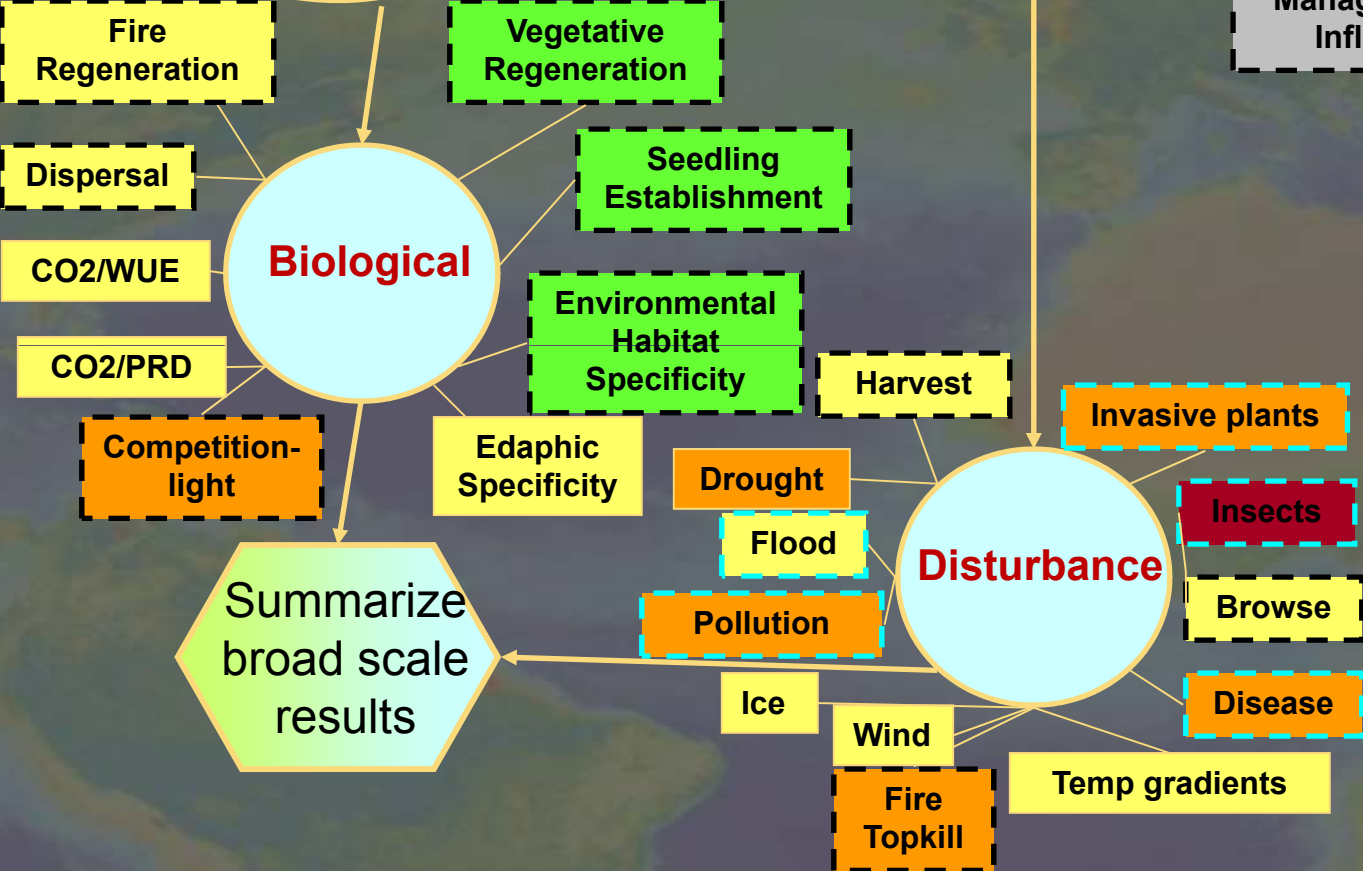
- No model, statistical or otherwise, can include all the biological or disturbance factors that may influence a species' response to climate change
- Need a method to incorporate other influences – modifying factors
- Glean literature and generate a scoring system to rate 21 factors



White Ash

DISTRIB-SHIFT model outputs

Manager Cannot Influence
Manager Regional Influence
Manager Local Influence

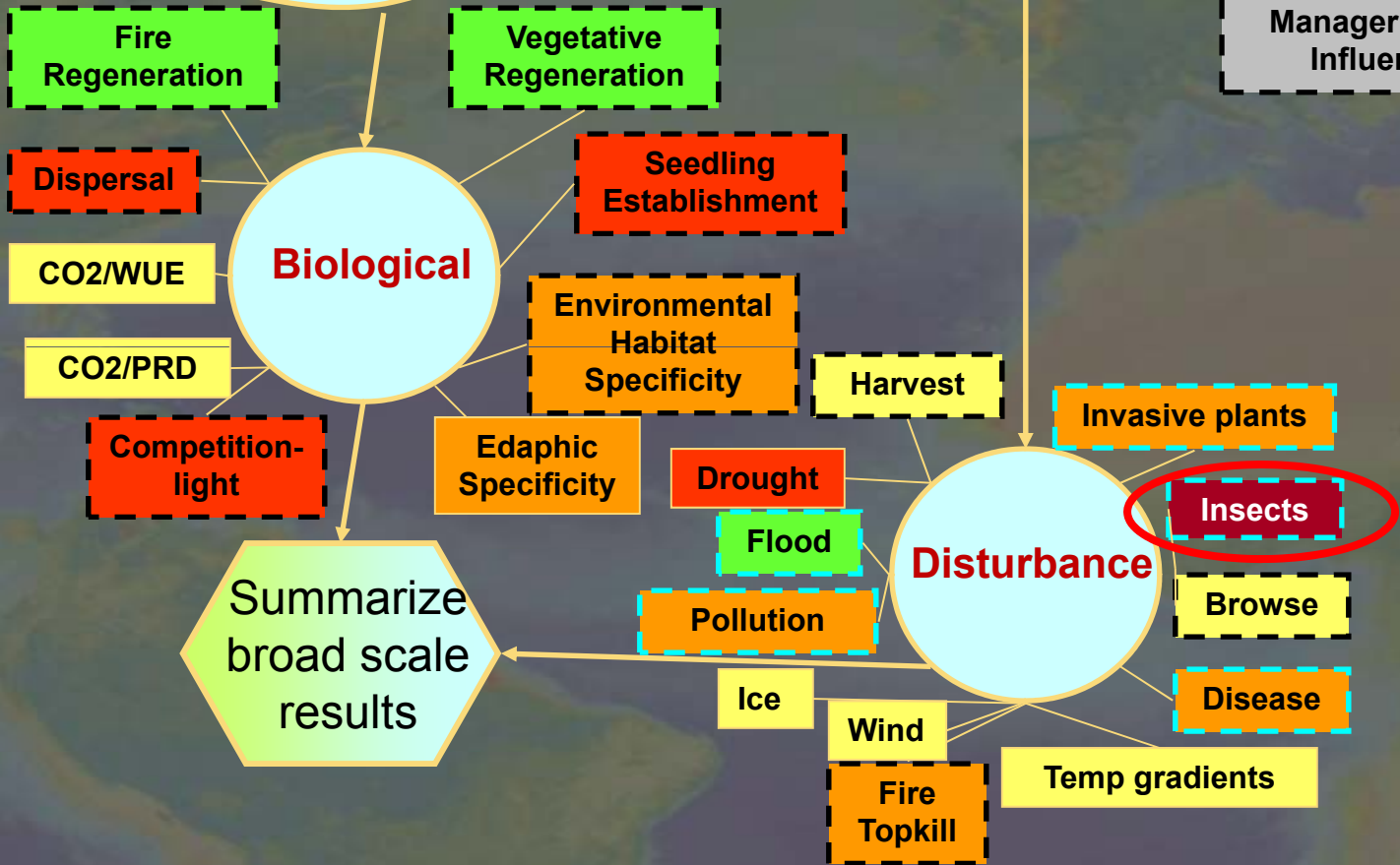


V Hi Pos
High pos
Low pos
Minimal
Low neg
High neg
V Lo neg

**Black
Ash**

**DISTRIB-
SHIFT model
outputs**

**Manager Cannot
Influence**
**Manager Regional
Influence**
**Manager Local
Influence**

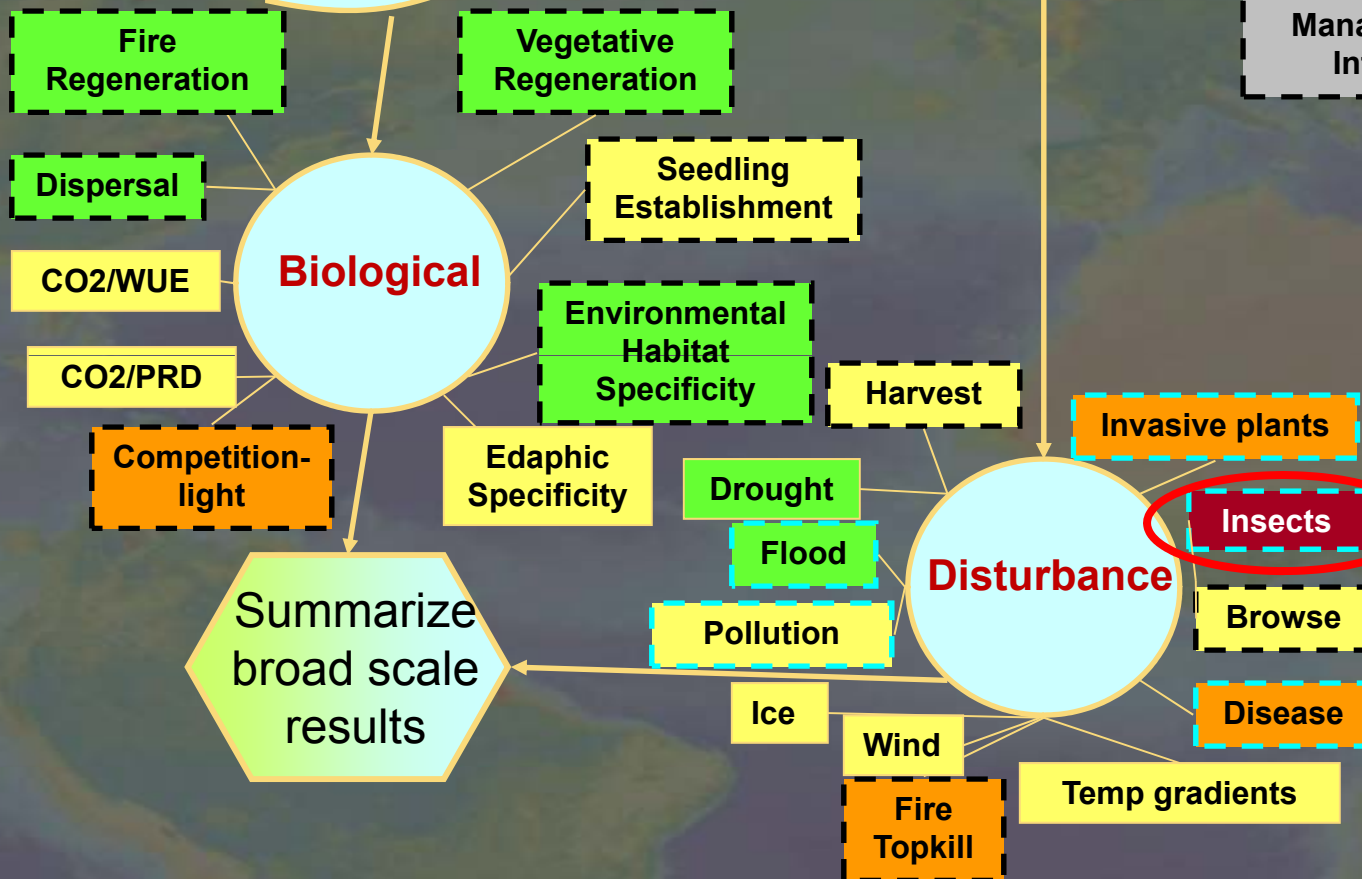


V Hi Pos
High pos
Low pos
Minimal
Low neg
High neg
V Lo neg

Green Ash

DISTRIB-
SHIFT model
outputs

Manager Cannot
Influence
Manager Regional
Influence
Manager Local
Influence



V Hi Pos
High pos
Low pos
Minimal
Low neg
High neg
V Lo neg

Red Maple

DISTRIB-SHIFT model outputs

Manager Cannot Influence
Manager Regional Influence
Manager Local Influence

Fire Regeneration

Vegetative Regeneration

Dispersal

Seedling Establishment

CO2/WUE

CO2/PRD

Biological

Environmental Habitat Specificity

Harvest

Competition-light

Edaphic Specificity

Drought

Flood

Pollution

Ice

Wind

Fire Topkill

Disturbance

Invasive plants

Insects

Browse

Disease

Temp gradients

Summarize broad scale results

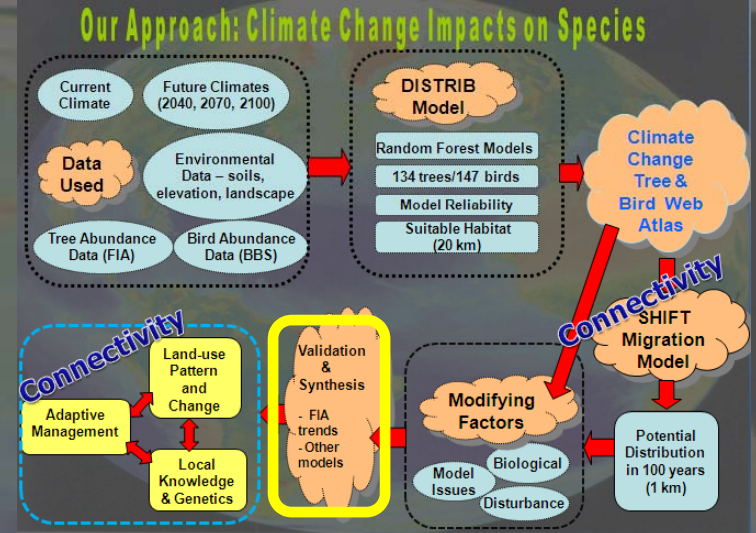
Land use change

Local knowledge & Genetics

Potential future tree importance

V Hi Pos
High pos
Low pos
Minimal
Low neg
High neg
V Lo neg

Lessons Learned



Search for data to support (or not) the models

- Convergence of multiple models
 - e.g., Nielson et al. (MAPPS, MC1)
 - Mladenoff et al. (LANDIS-II)
- Documentations of species changes
 - e.g., northward or elevation expansions,
 - changes in forest types
- Other surrogate ways to determine possible trends
 - E.g., Woodall et al. (FIA data)

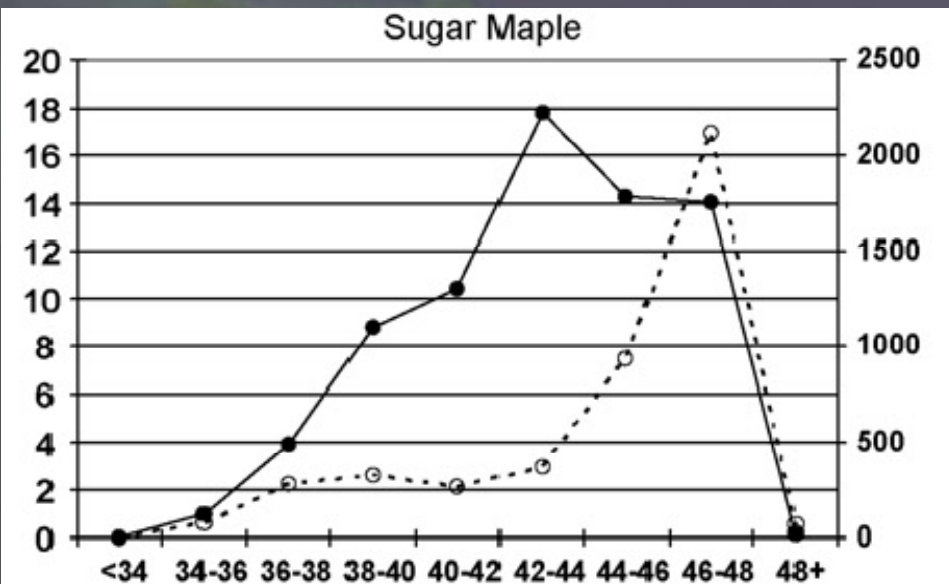
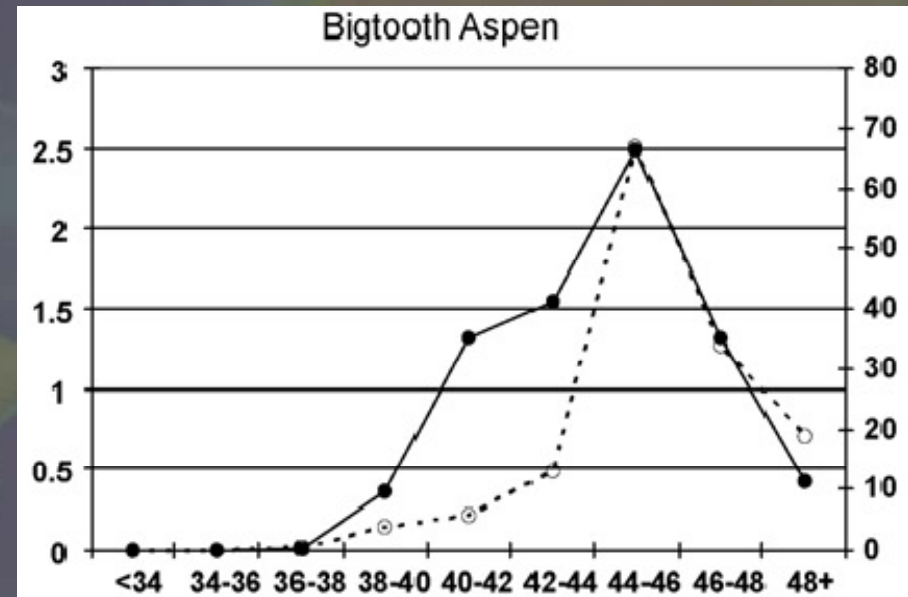


Contents lists available at ScienceDirect

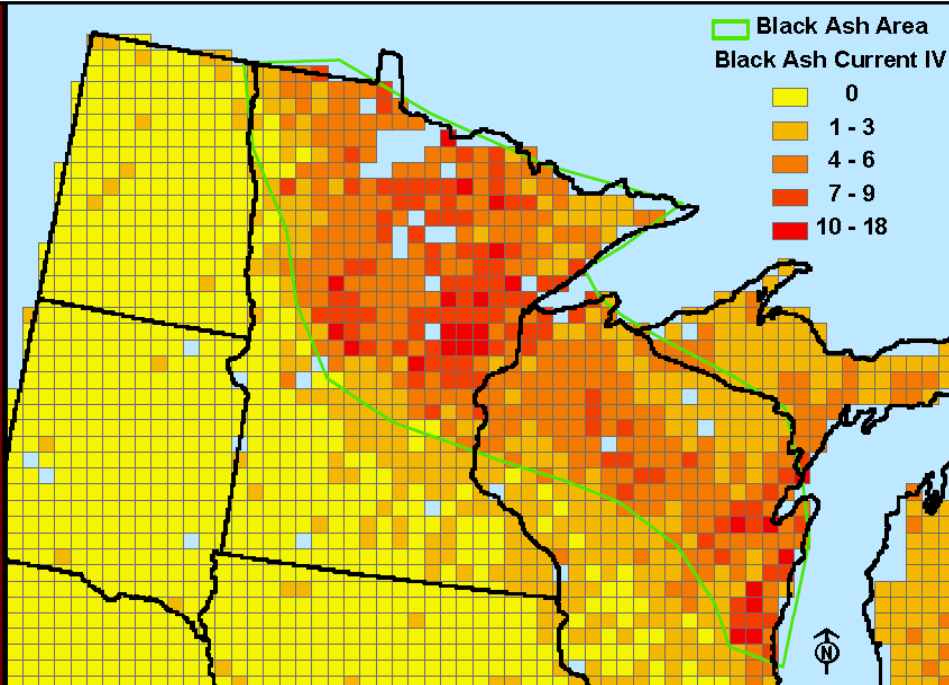
Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

An indicator of tree migration in forests of the eastern United States

C.W. Woodall^{a,*}, C.M. Oswalt^b, J.A. Westfall^c, C.H. Perry^a, M.D. Nelson^a, A.O. Finley^d**.13° North*******.46° North *******37 of 40 species have general tendencies in agreement with our models**

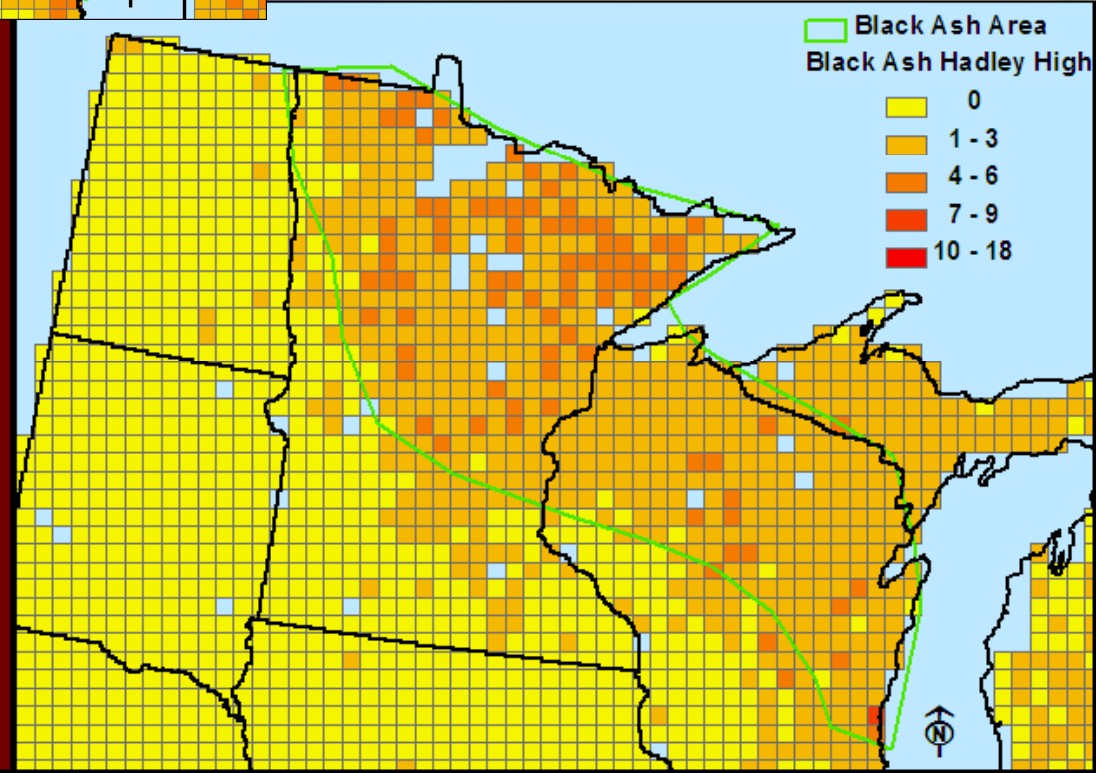
Black Ash Current Importance Value



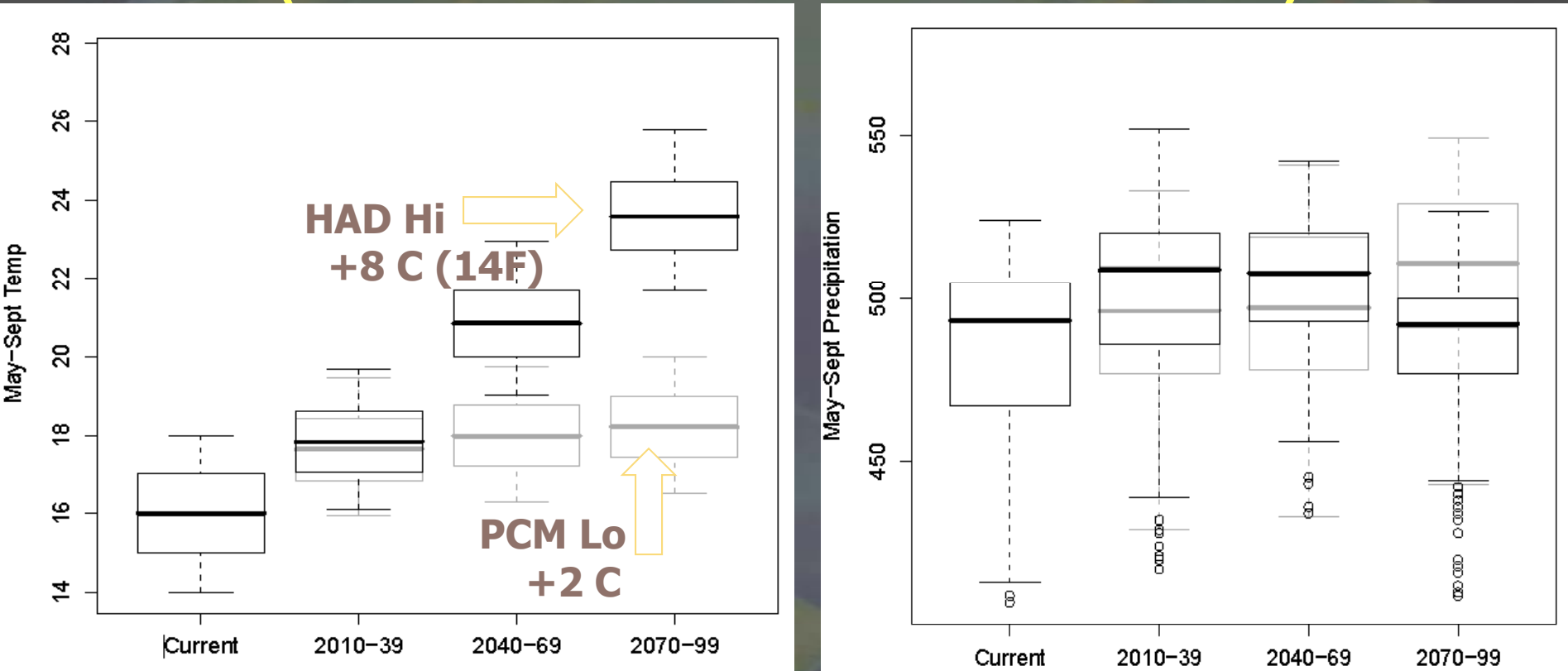
Black Ash “zone” and Habitat, 2000

Black Ash Habitat,
2100, Had Hi

Black Ash Potential Future Importance Value



Expected growing season changes (for northern Wisconsin)



**Growing season temperature higher and not much change
in precipitation = more physiological stress on biota**

Potential Changes for Tree Species

- Evaluated 85 species from the region
- Put in to 8 classes of impacts
 - Class 1: extirpated (2 species)
 - **Class 2: large decrease (6 species)**
 - Class 3: small decrease (14 species)
 - Class 4: no change (5 species)
 - Class 5: small increase (10 species)
 - **Class 6: large increase (23 species)**
 - **Class 7: new entry-high and low emissions (12 species)**
 - Class 8: new entry-high emissions (13 species)
- Score each species for modification factors to help managers interpret potential impacts and suggest adaptation strategies → Large tables!

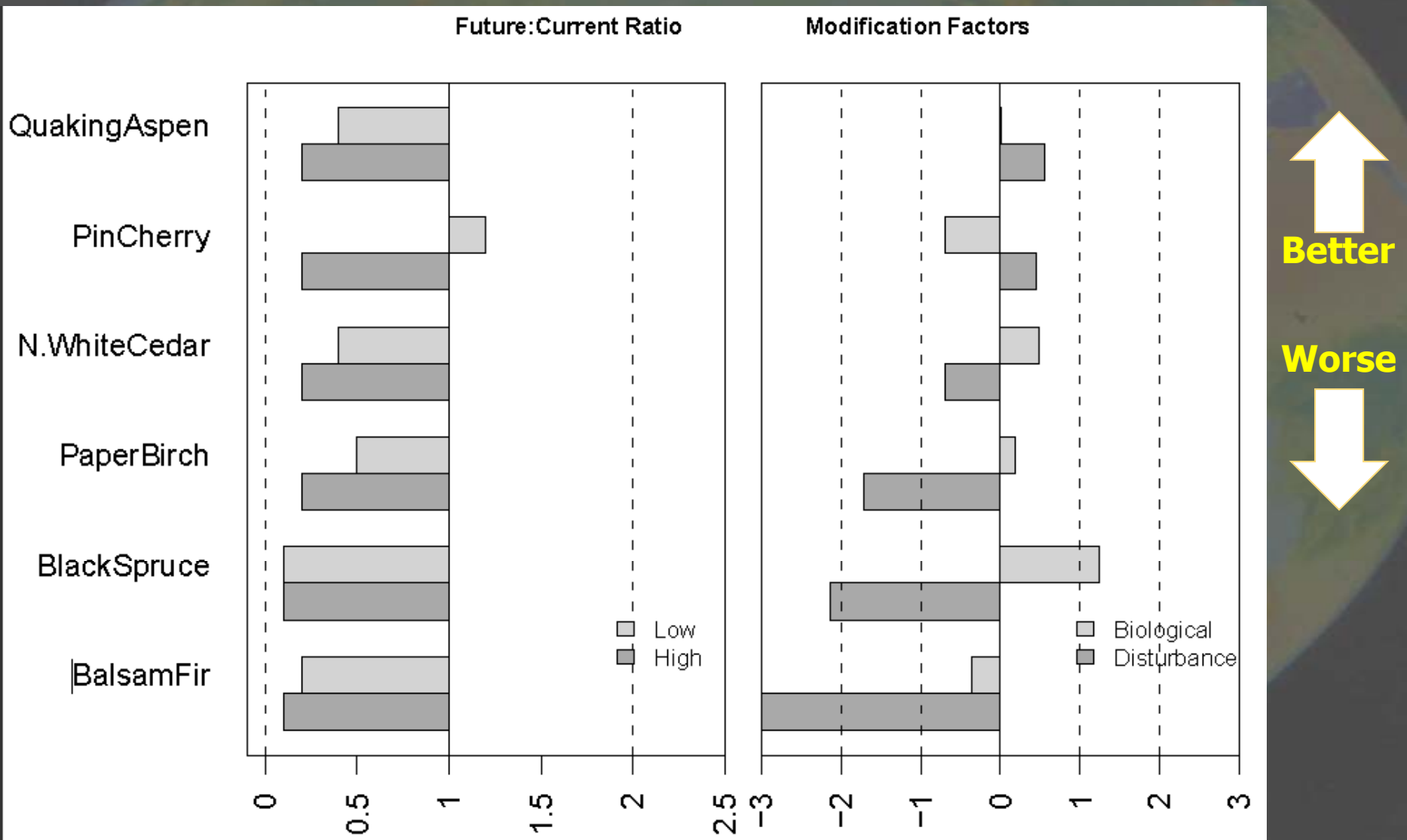
	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Pinus	serot	pauc	gamb	gamb	lobli	P		GCM35	GCM35	Modli	slane	summe	sum	exi		
2	513	168	28	82	4	8	1	132	8.85	8.88	8.88	1.00	american maple	Rare virginiana			
3	584	58	79	82	4	1	1	132	8.85	8.88	8.88	1.00	hatteras	Virginia virginiana			
4	12	2551	784	534	172	479	8.27	8.45	8.88	8.88	2.00	hatteras	Rare virginiana				
5	35	2838	548	136	117	117	8.1	8.1	8.88	8.88	2.00	black spruce	Picea mariana				
6	241	1433	666	451	326	288	8.45	8.45	8.88	8.88	2.00	southern white oak	Thuja occidentalis				
7	375	3513	1838	1548	535	558	8.57	8.57	8.88	8.88	2.00	paper birch	Betula papyrifera				
8	746	11234	5383	4874	2857	2841	8.48	8.48	8.88	8.88	2.00	quaking aspen	Populus tremuloides				
9	751	484	487	28	1	1	1	132	8.85	8.88	8.88	1.00	pin oak	Quercus prinus			
10	74	1554	1837	345	278	746	8.1	8.1	8.88	8.88	2.00	hatteras	Larix laricina				
11	34	583	342	348	276	276	8.54	8.55	8.88	8.88	2.00	white spruce	Picea glauca				
12	185	1782	1933	1938	1184	1185	8.78	8.78	8.88	8.88	2.00	jack pine	Pinus banksiana				
13	123	883	1866	1783	472	679	1.28	1.28	8.88	8.88	2.00	southern white pine	Pinus strobus				
14	261	236	347	274	472	464	1.17	1.17	8.88	8.88	2.00	southern white pine	Taxus canadensis				
15	316	3527	3751	3458	2886	2741	1.86	1.86	8.88	8.88	2.00	red maple	Rare virginiana				
16	318	3537	3364	3138	1832	1635	8.34	8.34	8.88	8.88	2.00	sugar maple	Rare virginiana				
17	371	562	385	281	162	158	8.63	8.63	8.88	8.88	2.00	yellow birch	Betula alleghaniensis				
18	543	2768	1351	1827	1478	1336	8.78	8.78	8.88	8.88	2.00	black oak	Pinus strobus				
19	631	4	2	2	2	2	8.58	8.58	8.88	8.88	2.00	water lily	Hydra aquatica				
20	741	1648	233	478	576	687	8.18	8.23	8.88	8.88	2.00	hatteras	Populus balsamifera				
21	743	1883	338	733	352	382	8.32	8.73	8.88	8.88	2.00	hatteras	Populus grandidentata				
22	763	484	333	333	252	235	8.84	8.33	8.88	8.88	2.00	black oak	Pinus strobus				
23	883	2375	3516	3784	2116	1879	1.48	1.56	8.88	8.88	2.00	red pine	Pinus strobus				
24	125	1233	1315	1454	1178	1877	1.86	1.17	8.88	8.88	2.00	green oak	Pinus strobus				
25	544	2284	1358	2253	2783	2641	8.83	1.81	8.88	1.81	4.00	american white oak	Quercus ellipsoidalis				
26	883	474	536	657	531	546	1.13	1.33	8.88	1.13	4.00	american white oak	Pinus strobus				
27	351	2141	2337	2633	2384	2213	1.12	1.26	8.88	1.12	4.00	american white oak	Pinus strobus				
28	377	63	58	55	68	78	8.72	8.88	8.88	8.88	1.81	red pine	Pinus strobus				
29	37	13	31	31	25	23	1.63	1.63	1.32	1.32	5.00	red spruce	Rare virginiana				
30	315	17	16	28	27	23	8.34	1.65	1.32	1.32	5.00	red spruce	Rare virginiana				
31	356	2	3	11	3	8	8.58	5.58	4.58	4.58	5.00	red spruce	Rare virginiana				
32	373	3	8	17	22	28	2.67	5.67	7.33	7.33	5.00	red spruce	Rare virginiana				
33	331	225	382	323	417	421	1.34	1.46	1.46	1.46	5.00	american white oak	Pinus strobus				
34	452	11	5	5	128	151	8.45	8.45	18.31	18.31	5.00	american white oak	Pinus strobus				
35	461	12	5	5	181	166	8.58	8.58	8.42	8.42	5.00	american white oak	Pinus strobus				
36	781	323	1878	1382	1317	1325	1.16	1.41	1.41	1.41	5.00	american white oak	Pinus strobus				
37	762	817	2282	2141	1381	1183	2.78	2.62	1.63	1.63	5.00	black oak	Pinus strobus				
38	823	2755	2383	3488	3877	4813	1.86	1.26	1.41	1.41	5.00	black oak	Pinus strobus				
39	68	84	1183	2533	4877	3883	13.13	38.87	48.34	48.34	5.00	american white oak	Pinus strobus				
40	313	1673	1368	2628	3522	3734	1.17	1.57	2.18	2.18	2.26	hatteras	Rare virginiana				
41	317	272	1881	1437	1864	1388	3.68	5.58	6.85	6.85	5.00	hatteras	Rare virginiana				
42	373	12	38	83	142	175	2.58	6.32	11.83	14.58	5.00	hatteras	Rare virginiana				
43	482	132	444	583	678	714	2.31	3.84	3.43	3.72	5.00	hatteras	Rare virginiana				
44	487	258	863	1831	1114	1884	3.45	4.36	4.46	4.54	5.00	hatteras	Rare virginiana				
45	462	115	832	1478	2518	2663	7.23	12.78	21.38	23.21	5.00	hatteras	Rare virginiana				
46	531	175	378	363	441	486	2.16	2.11	2.32	2.32	5.00	hatteras	Rare virginiana				
47	541	477	854	846	1837	1882	1.73	1.77	2.17	2.18	5.00	hatteras	Rare virginiana				
48	682	33	526	324	1683	1741	15.34	28.88	51.88	52.71	5.00	hatteras	Rare virginiana				
49	641	23	134	211	888	638	5.83	3.17	26.43	38.3	5.00	hatteras	Rare virginiana				
50	682	15	326	785	2857	2218	24.73	52.33	137.13	147.8	5.00	hatteras	Rare virginiana				
51	742	264	627	1228	2783	2642	2.38	4.65	18.34	18.81	5.00	hatteras	Rare virginiana				
52	766	23	25	78	584	526	1.83	3.84	21.31	22.87	5.00	hatteras	Rare virginiana				
53	882	817	1837	2252	2882	2833	2.32	2.76	2.55	2.43	5.00	hatteras	Rare virginiana				
54	884	33	72	118	255	247	1.85	3.83	6.54	6.53	5.00	hatteras	Rare virginiana				
55	838	18	64	113	337	427	6.48	11.38	33.78	42.78	5.00	hatteras	Rare virginiana				
56	837	488	1311	1584	2814	2163	2.63	3.88	4.13	4.43	5.00	hatteras	Rare virginiana				
57	381	12	281	358	1355	1615	16.75	23.83	112.32	134.58	5.00	hatteras	Rare virginiana				
58	321	58	53	135	443	517	1.18	3.38	8.38	18.34	5.00	hatteras	Rare virginiana				
59	322	263	671	373	1454	1582	2.43	3.62	5.41	5.58	5.00	hatteras	Rare virginiana				
60	372	2286	3887	8556	5257	5448	4.38	4.53	2.35	2.28	5.00	hatteras	Rare virginiana				
61	375	254	364	1372	1631	1747	3.88	5.48	6.56	6.76	5.00	hatteras	Rare virginiana				
62	331	8	26	181	246	133	1e6	1e6	1e6	1e6	7.00	hatteras	Rare virginiana				
63	483	1	82	113	337	368	82.88	113.88	337.88	368.88	7.00	hatteras	Rare virginiana				
64	483	1	38	61	333	381	38.88	61.88	333.88	381.88	7.00	hatteras	Rare virginiana				
65	471	8	14	75	555	553	1e6	1e6	1e6	1e6	7.00	hatteras	Rare virginiana				
66	431	8	32	121	335	358	1e6	1e6	1e6	1e6	7.00	hatteras	Rare virginiana				
67	552	5	224	553	1424	1565	44.88	118.88	284.88	315.88	7.00	hatteras	Rare virginiana				
68	621	8	14	8	151	163	1e6	1e6	1e6	1e6	7.00	hatteras	Rare virginiana				
69	731	8	28	23	238	313	1e6	1e6	1e6	1e6	7.00	hatteras	Rare virginiana				
70	817	1	8	68	253	245	8.88	68.88	253.88	245.88	7.00	hatteras	Rare virginiana				
71	826	8	22	36	478	544	1e6	1e6	1e6	1e6	7.00	hatteras	Rare virginiana				
72	835	8	3	53	1463	1785	1e6	1e6	1e6	1e6	7.00	hatteras	Rare virginiana				
73	331	4	78	188	482	416	13.58	27.88	188.58	184.88	7.00	hatteras	Rare virginiana				
74	131	8	1	1	48	47	HA	1e6	1e6	1e6	8.88	hatteras	Rare virginiana				
75	372	1	1	1	44	36	1.88	8.88	44.88	36.88	8.88	hatteras	Rare virginiana				
76	484	8	8	1	145	162	HA	1e6	1e6	1e6	8.88	hatteras	Rare virginiana				
77	485	8	8	12	37	35	HA	1e6	1e6	1e6	8.88	hatteras	Rare virginiana				
78	488	8	8	8	312	353	HA	1e6	1e6	1e6	8.88	hatteras	Rare virginiana				
79	521	8	8	8	33	148	HA	1e6	1e6	1e6	8.88	hatteras	Rare virginiana				
80	571	1	8	6	58	77	8.88	6.88	58.88	77.88	8.88	hatteras	Rare virginiana				
81	611	8	8	4	71	78	HA	1e6	1e6	1e6	8.88	hatteras	Rare virginiana				
82	633	2	3	3	34	187	1.58	1.58	47.88	53.58	8.88	hatteras	Rare virginiana				
83	886	8	4	11	158	158	1e6	1e6	1e6	1e6	8.88	hatteras	Rare virginiana				
84	824	8	8	12	521	648	HA	1e6	1e6	1e6	8.88	hatteras	Rare virginiana				
85	832	1	8	4	78	78	8.88	4.88	78.88	78.88	8.88	hatteras	Rare virginiana				

↑
Losers

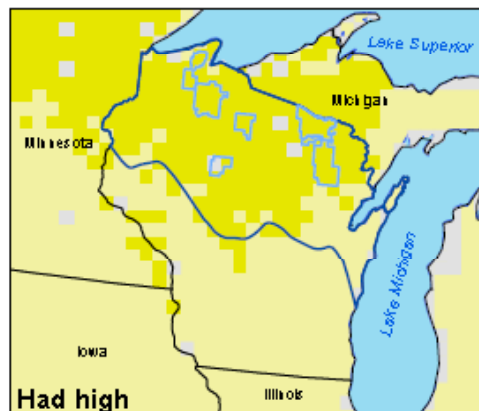
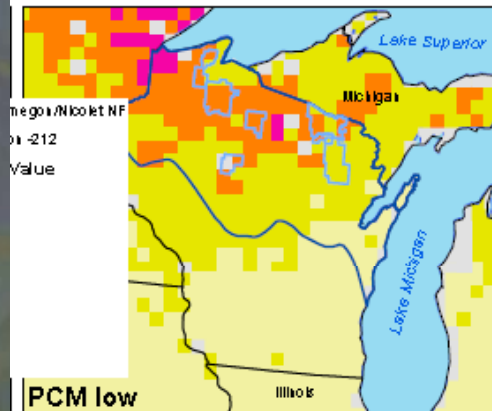
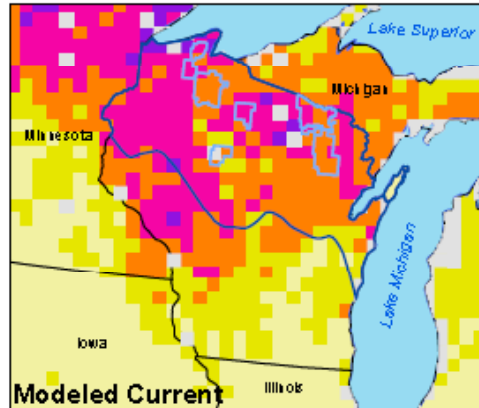
↓
Gainners

↓
Migrators

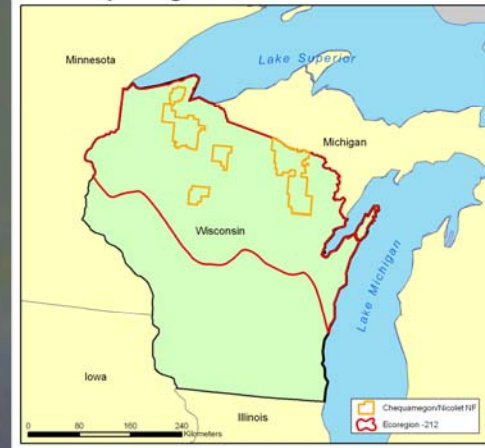
Large Decreasers (Cl. 2)



Paper Birch



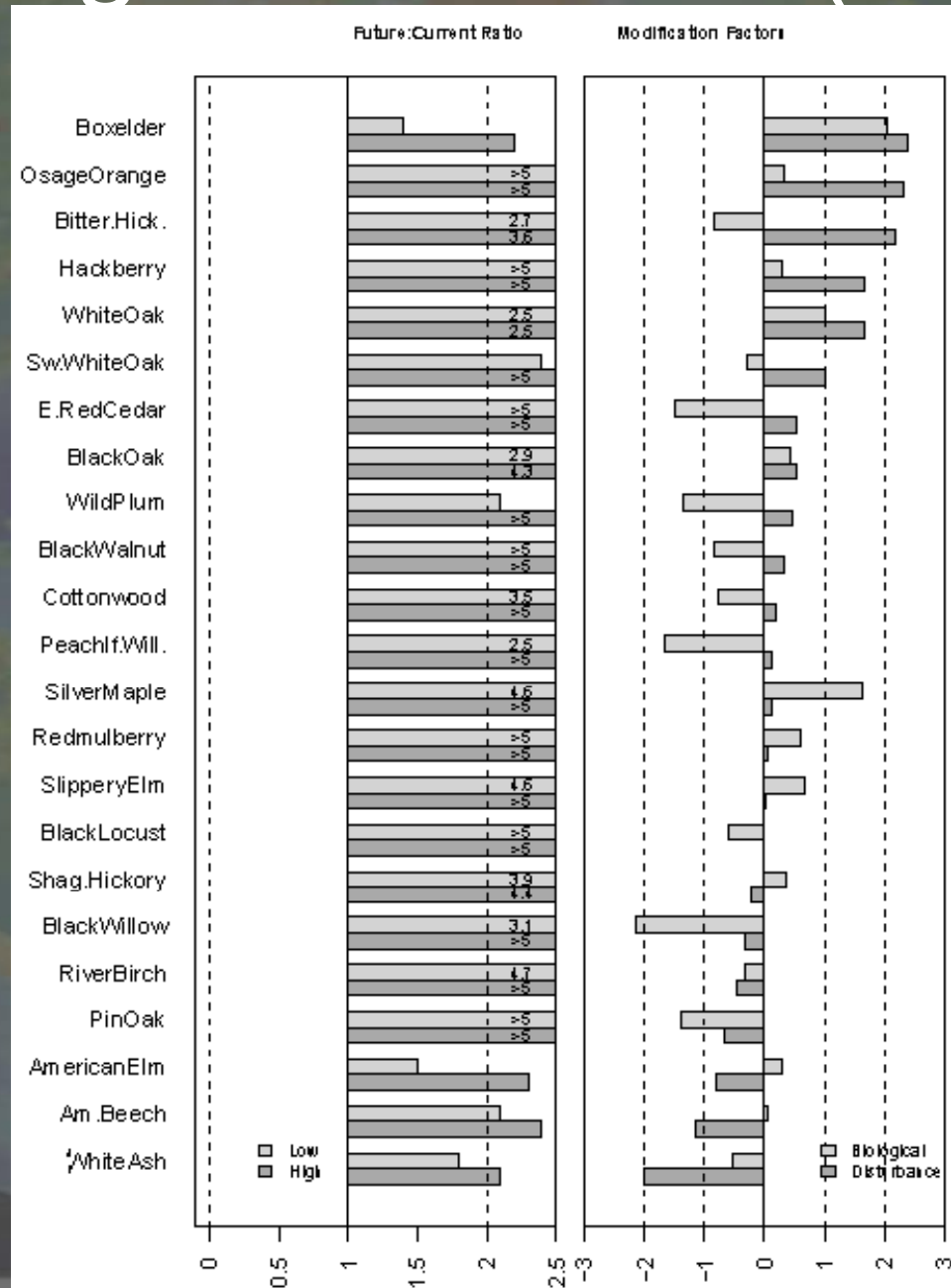
Chequamegon/Nicolet National Forest



**Class 2,
Large Decreasers**

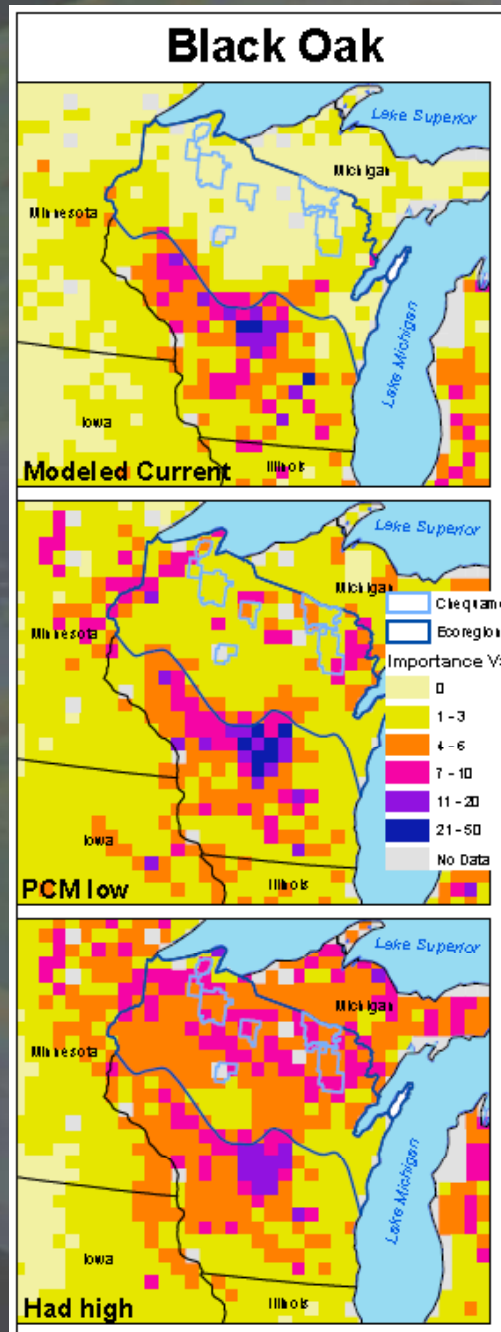
**(especially under Had High
scenario of climate change)**

Large Increases (Cl. 6)



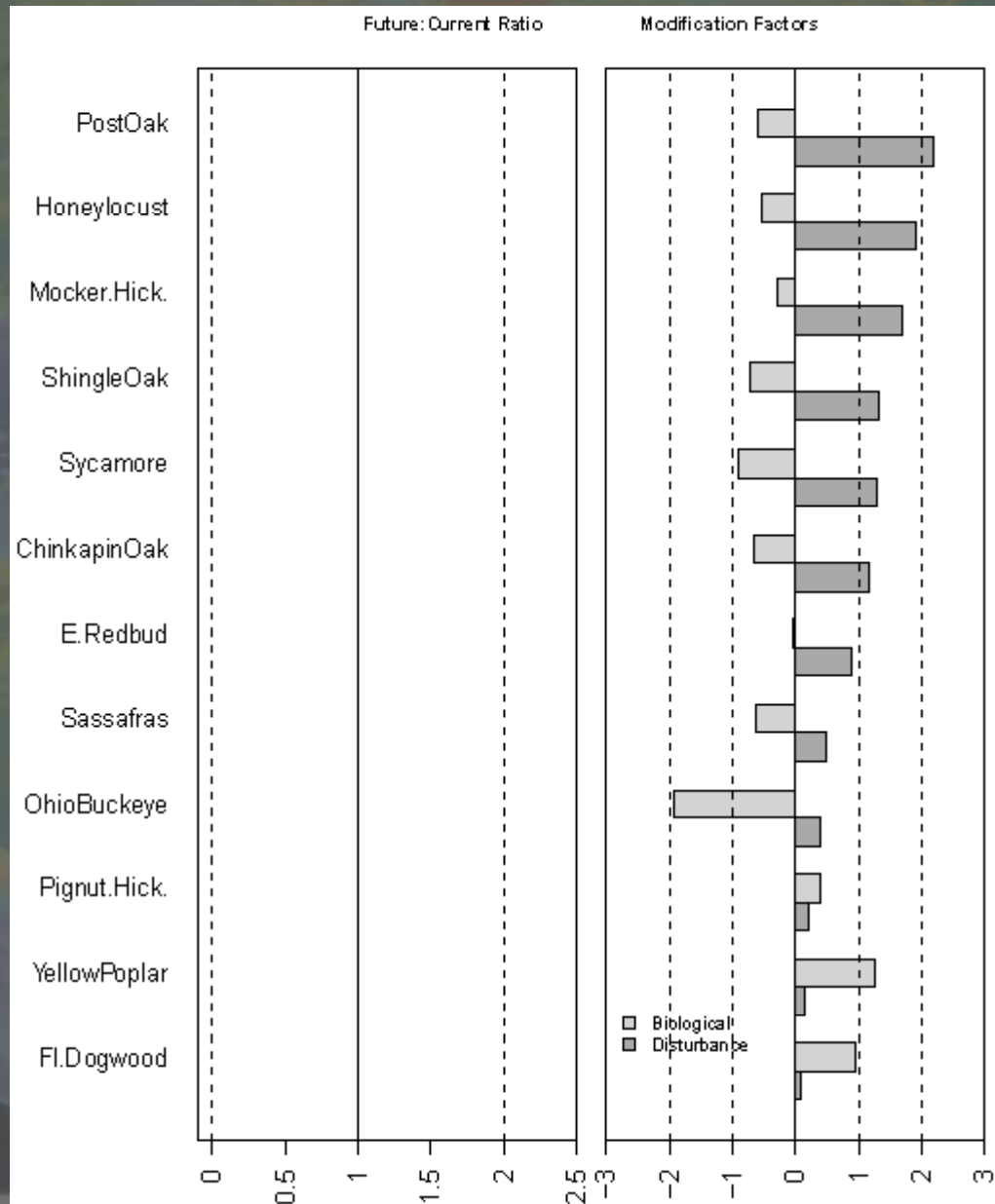
Better

Worse



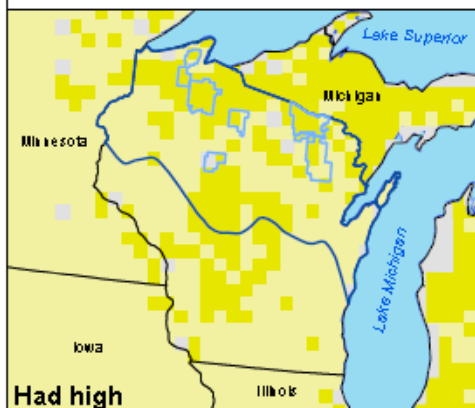
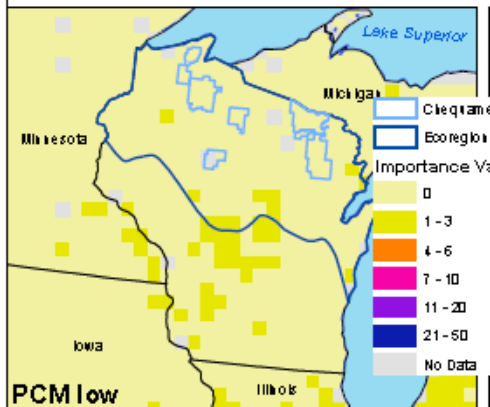
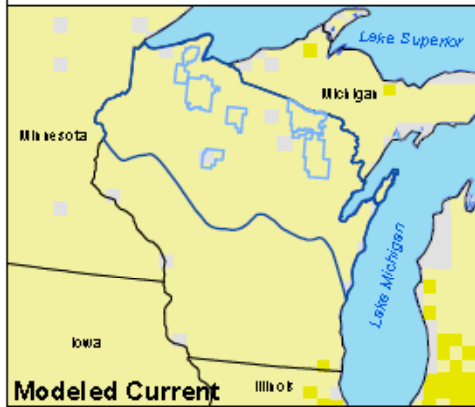
**Class 6,
Large Increases**

New Migrants, low or high

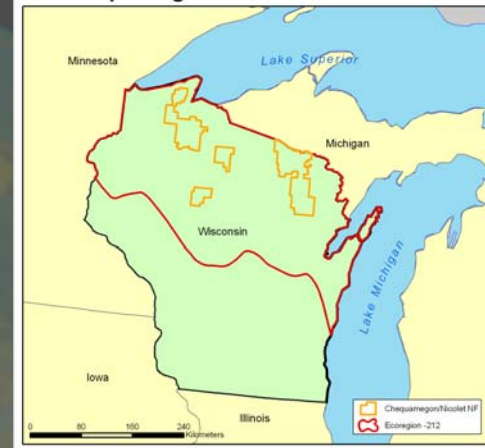



Better

Yellow Poplar

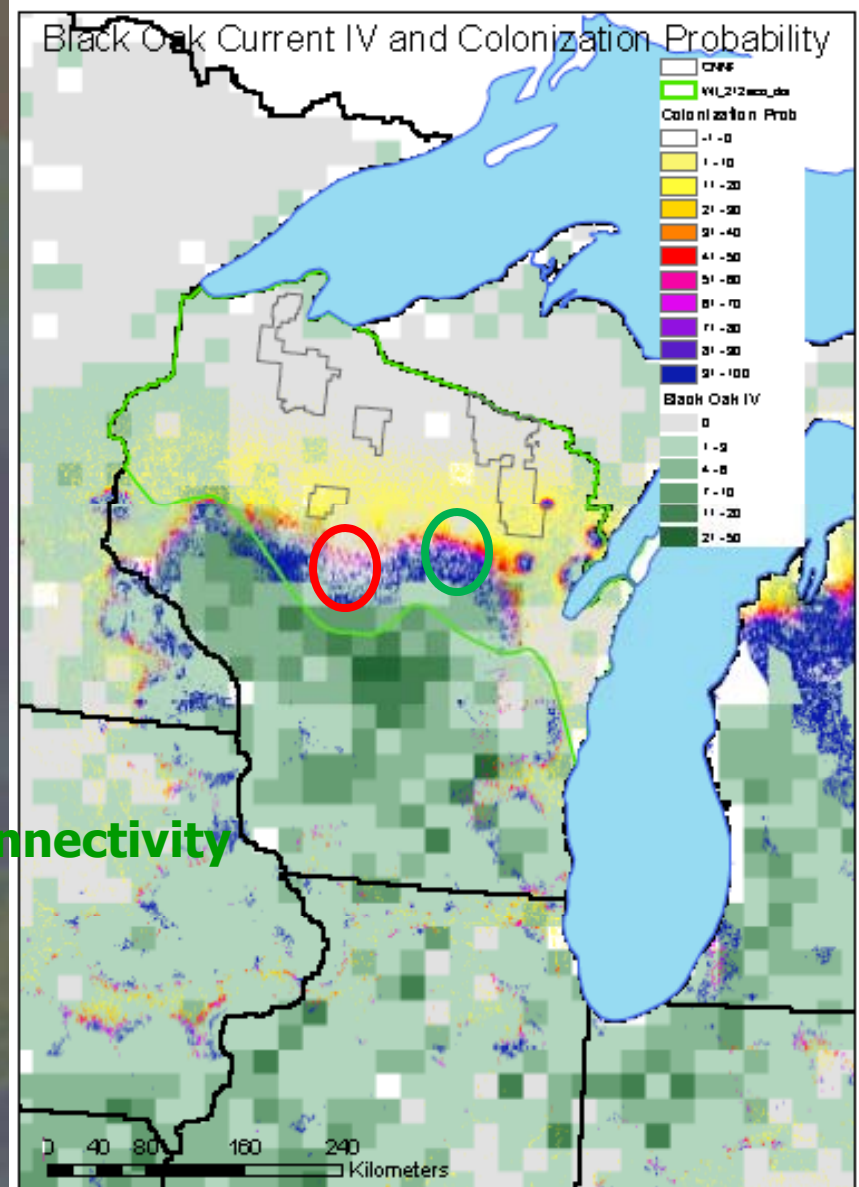
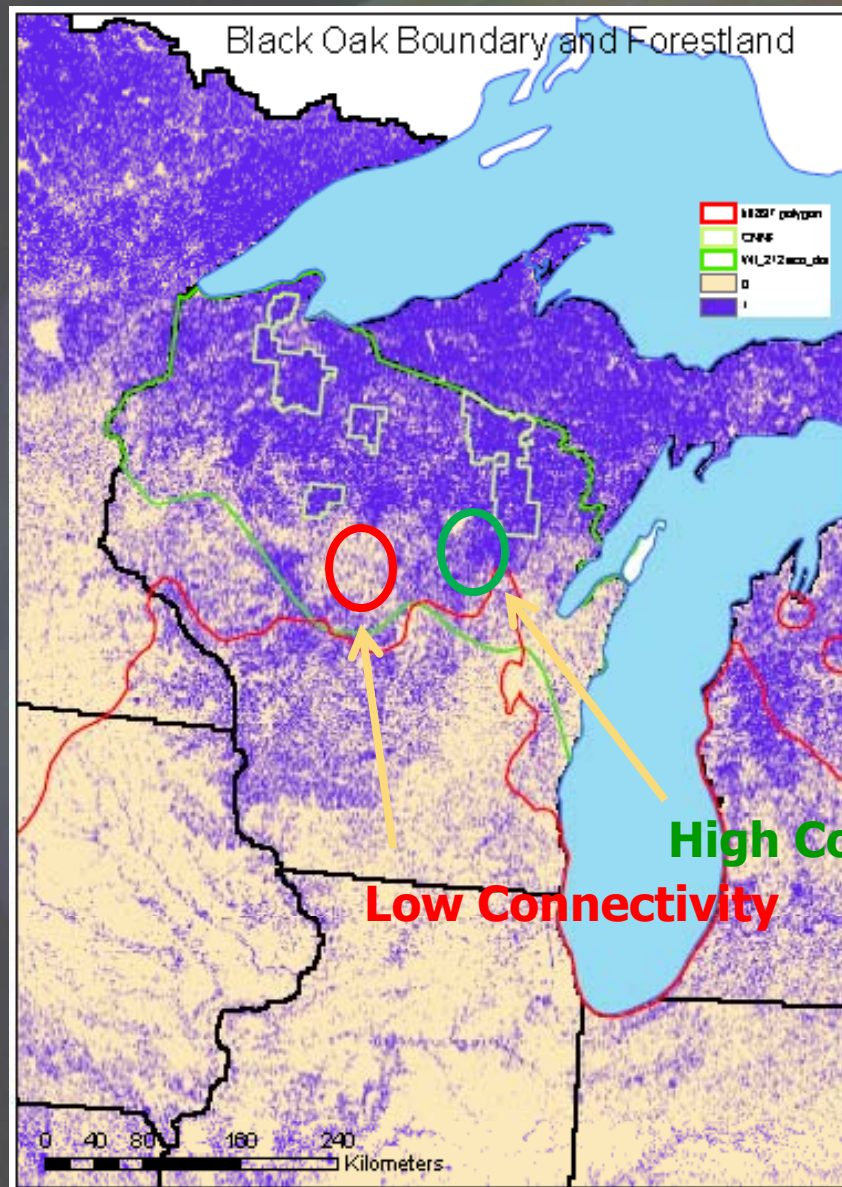


Chequamegon/Nicolet National Forest



Class 7
New Migrants,
Any scenario
of climate change.

SHIFT (preliminary): Black oak potential migration by 2100



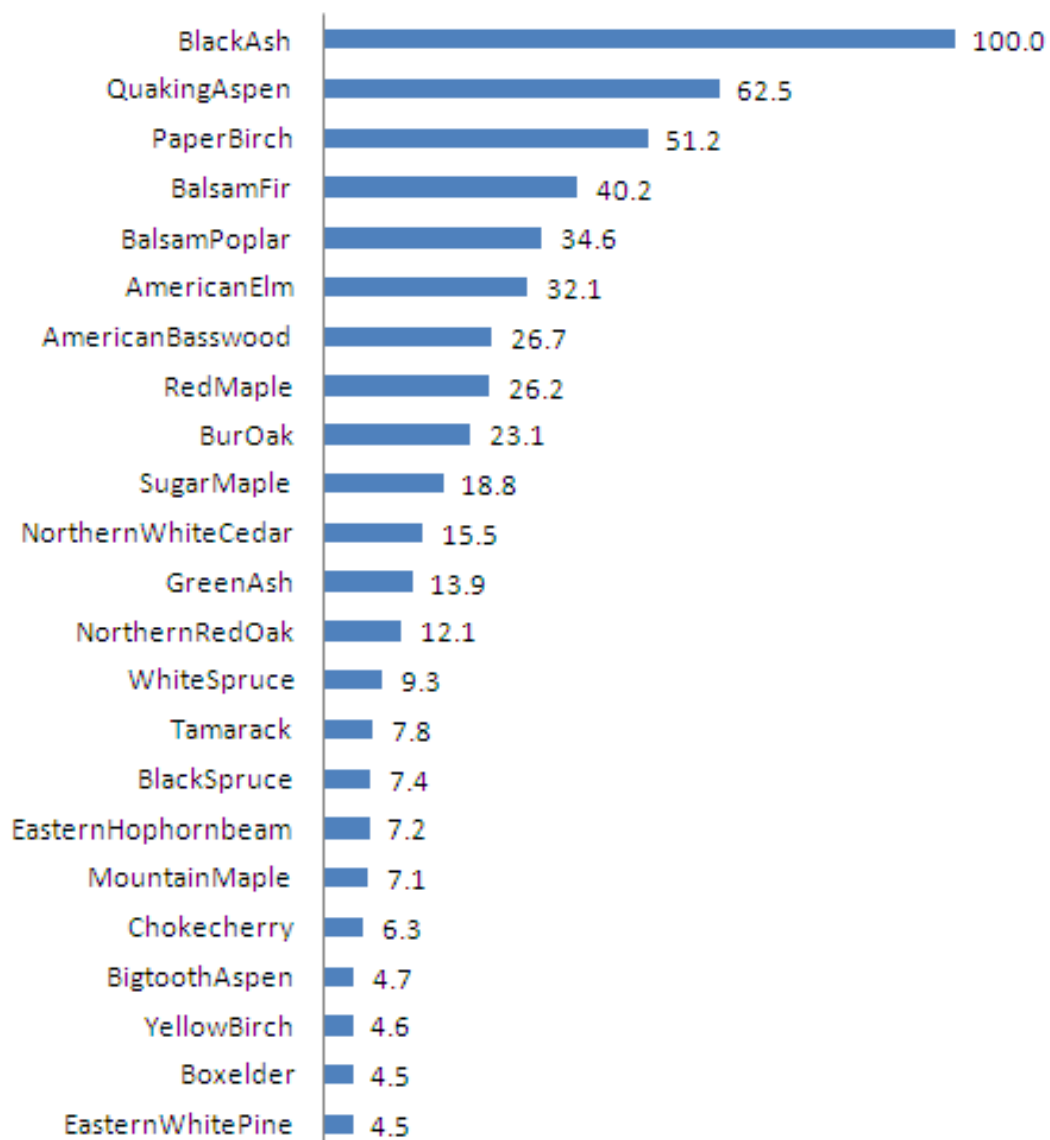
Forest Density (NLCD data 2000)

Shift (Preliminary) Output on
Current Black Oak IV

Evaluate FIA plots for MN

- FIA from last periodic inventory, not precise locations
- Of 9427 plots, 2176 (23%) had black ash
- Of these, we evaluated 23 species co-occurring on >4% of the plots

Percent of B.A. Plots with B.A.



Species with High Potential to Replace Black Ash in the long term

- Already live with black ash, either in MN or in points south (OH or MI)
- Have potential to do well or at least OK under climate change – according to our DISTRIB models
- Have characteristics which allow it to do well under predicted outcomes of climate change – according to our ModFactors

6 Large Inc.

5 Small Inc.

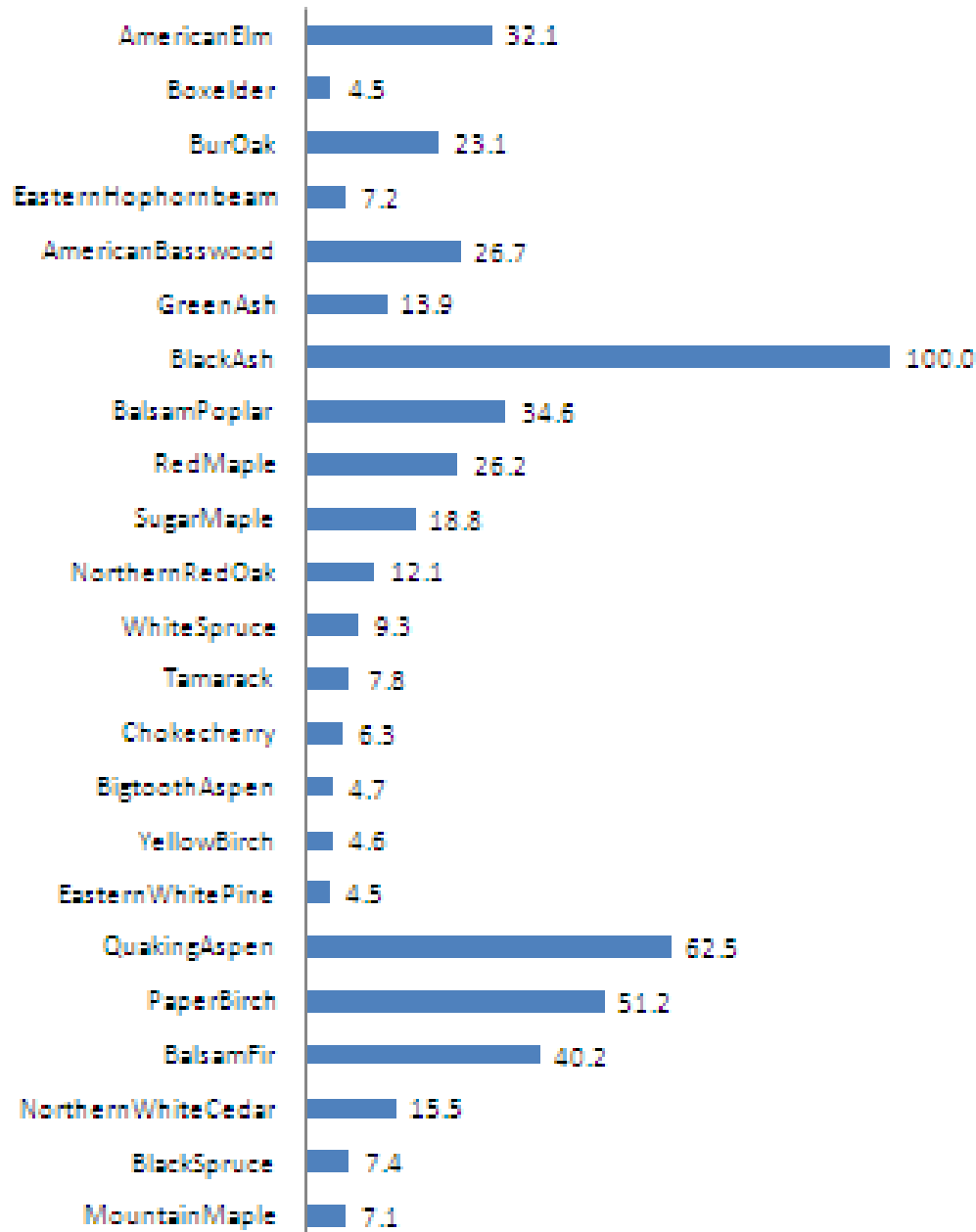
4 No Change

3 Small Dec.

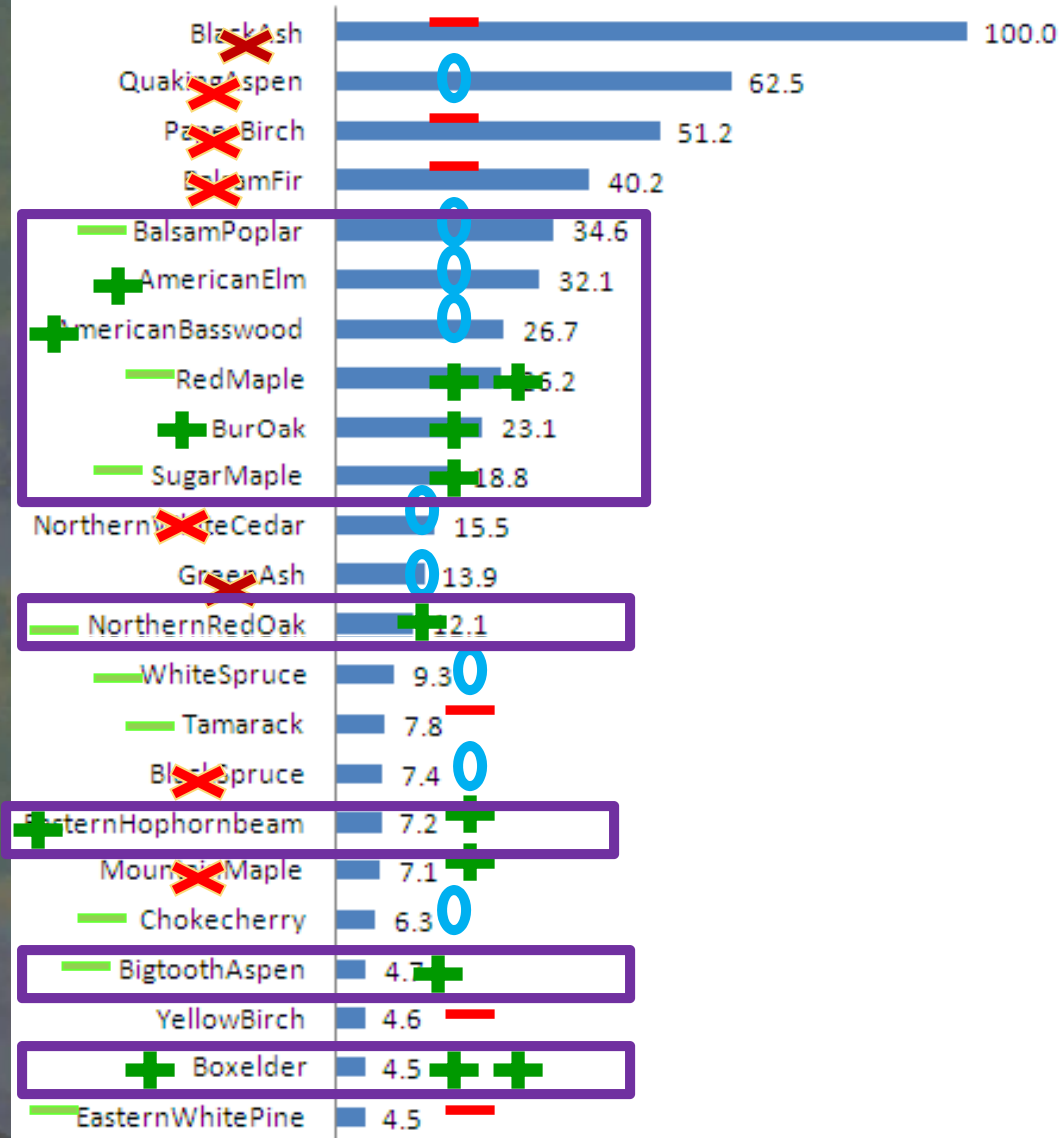
2 Large Dec.

1 Extirpated

Percent of FIA with Black Ash



Percent of B.A. Plots with B.A. Climate Ch. Mod Factors



Some summary thoughts on ash and their replacements

- The short-term disturbance of EAB infestation will drastically overwhelm longer term impacts of climate change.
- Some of the species on list of potential replacements may seem ridiculous to consider as possible replacements. Some will be ridiculous but I encourage being generous in selecting species for further analysis and testing.
- Very subtle variations in topography and soils can greatly influence which species may be appropriate. Carefully control and map these factors to minimize mis-matching.

Management Implications

Potential **management implications** resulting from the above trends include:

- Encourage increased connectivity for increaser species.
- Evaluate potential for assisted migration.
- Encourage retention of refugia which may allow persistence of decreaser species.
- Prepare for additional costs likely required to maintain forest health due to increased stress and disturbances (e.g., insect pests, diseases, fire, ice, drought).
- Prepare for quite dramatic changes in some iconic north woods species!
- This is a terrific application for adaptive management!



Thank you!

For further information, consult
our web atlas

(www.nrs.fs.fed.us/atlas)

or contact me

(liverson@fs.fed.us)